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Airgas to Provide Jobs, Welder Training to War Veterans

Airgas, Inc., Radnor, Pa., has set a goal to hire 100 veterans who have served in Iraq and Afghanistan over the next 12 months. The company will also offer its Welding 101 course to any veteran interested in exploring a welding career.

Additionally, the company has pledged $300,000 to Operation Homefront, a charity that supports America’s soldiers by providing emergency assistance and moral support to the families troops leave behind when they are deployed and to wounded service members when they return home. The donation will be paid in increments of $100,000 per year over the next three years, with 70% going toward Operation Homefront’s projects to assist wounded soldiers.

U.S. Awards $92 Million Contract to Teledyne Brown

U.S.E.C. Inc., Bethesda, Md., awarded a $92 million contract to Teledyne Brown Engineering Inc., Huntsville, Ala., to manufacture 540 gas centrifuge service modules for its American Centrifuge uranium-enrichment program.

Critical to the operation of the centrifuge machines, service modules are welded, steel frame structures with pipe headers and valves, control and instrument cabling, ventilation ductwork, and electrical distribution cables.

Teledyne Brown recently opened a new manufacturing facility in Huntsville to handle this contract. It expects to add nearly 200 jobs at the facility, which is being expanded from 130,000 to 206,000 sq ft needed for production operations.

North American Robot Orders Decline 17% in First Quarter

North American robotics companies reported new orders sold to North American manufacturers fell 17% in the first quarter of 2008 from the same quarter in 2007, but revenue rose 5%. Additionally, orders to nonautomotive companies surged, an encouraging sign for future robotics growth, according to the Robotic Industries Association (RIA), Ann Arbor, Mich.

A total of 3828 robots valued at $288.1 million were sold in the opening quarter by North American-based robotics companies, according to new figures released by RIA. When sales to companies outside North America are included, the totals are 4281 robots valued at $311.3 million, a decline of 15% in units and a gain of 6% in revenue.

Also, orders to automotive manufacturers and their suppliers fell 34% in units.

“Welding and coating/dispatching orders showed big declines because these are heavily tied to automotive. Assembly and material-handling applications showed gains because many of these applications are also extensively used in nonautomotive industries,” said Jeffrey A. Burnstein, executive vice president of RIA.

Plastic Welding Certification Facility Offers Courses

A new plastic welding training center offers plastic fabricator education, hands-on training, and certification in plastic welding and portable extrusion welding in accordance with The Welding Institute (TWI) specification, thanks to STAR Process Heat Systems LLC and RRE Inc. — The Plastic Welding School. The two organizations recognized the need to offer a formal training program and facility on how to weld plastics. The program is based on European CEN (Committee for Standardization) and DVS (German Welding Society) plastic welding standards.

The training facility for RRE Inc. — The Plastic Welding School is located at STAR Process Heat Systems LLC in Farmingdale, N.J. The class schedule is the third week of each month. Standard courses offered are as follows: ATC61 — 3 Day Extrusion Welding; ATC62 — 2 Day Gas Appreciation; ATC66 — 5 Day Hot Gas Welding; and ATC68 — 3 Day Plastic Welders Certification.

R.B.A. Doubles Manufacturing Space

Broadwind Energy, Inc., Naperville, Ill., recently announced its heavy steel fabrication company, R.B.A. Inc., Manitowoc, Wis., a provider of subcontract machining, fabrication, refurbishing, welding, and assembly, has acquired a second facility. Located in Clintonville, Wis., it comprises approximately 60,000 sq ft. The company has begun hiring employees and expects to add approximately 40 people.
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The Many Rewards of Volunteerism

After many years of working for my livelihood, it dawned on me that besides being an employee of a company, I was actually a volunteer. After all, no one made me choose the company I worked for. I made the choice based on the work available, reputation of the company, salary, and workmates. I could leave employment at any time. What made me remain with the business? Was it the pay, the challenge of the work, working with others to reach a common goal? The reality was I remained an employee for all of those reasons and others.

When I came to grips with my volunteerism, my work actually seemed more pleasant. The thought that I could make an employment change if necessary was like a breath of fresh air. My mindset was changed forever.

I’ve belonged to several associations in my life, becoming a member for the usual reasons: boss asked me to, friend belonged, hoped to parlay my involvement into something for the better. I became a member of the American Welding Society in the same manner. As a manager I asked a coworker and friend — the fabrication supervisor at our company — to visit a welding school and give his take on its teaching methods and whether it was a place from which we could obtain welders. The owner of the school was on the local Section executive committee and invited my colleague to attend a Section meeting. The invitation was passed on to me, and together we attended. The rest is history. In 1993, I became a member of the AWS voluntarily as did the fabrication supervisor. Our reason was that we could associate with people with a goal common to ours. Welding and fabrication was my career choice, and with the American Welding Society I was able to associate with like-minded people — and we were all volunteers. Of course, at that time, little did I realize that this involvement would grow, but I found I was able to juggle the duties of the Section with my regular employment responsibilities. Over time, my responsibilities to the Section grew as well.

What keeps me volunteering and what maintains my interest is the work I do and the enthusiasm I feel from my family, each of the AWS staff members, and my fellow Board and Section members and their families. We are all united in supporting the welding community. Look at the makeup of the AWS Section leadership and national Board of Directors. All facets of the welding industry are present — from representatives of welding equipment manufacturers to educators to end users — and from such a variety of locations. Each of these people has his or her own reasons for volunteering.

I ask you to seek out others whom you feel could benefit from becoming a volunteer. An associate, supervisor, mentor, relative, friend may enjoy the challenges we volunteers face. Although juggling daily life and employment with planning a Section meeting, balancing the Section checkbook, arranging a plant tour, or other tasks seems like a lot of work, the time required is often not as much as it would at first seem. I’ve learned during my time as a volunteer that we have plenty of time to do the things we want to do.

My local Section is blessed with several businesses that volunteer to support a monthly meeting. Equipment vendors, technical colleges, end users, and inspection companies volunteer on an annual basis. Their efforts are so greatly appreciated. The cost of the food and beverages is paid by a businesses; members and guests attend at no cost. The cost to the business varies, but it can be up to several hundred dollars plus the effort of locating a guest speaker. What better way to showcase your business? This is a great way to volunteer if you feel that your time is restricted. We’ve found through this arrangement that Section member attendance has increased as has the involvement of many students. A scholarship is actually awarded to the student who attends the most Section meetings — another way in which volunteerism has its rewards.

I thank the friend who offered me a chance to join the AWS as a volunteer. He remains a member, became a CWI, and is very active as a Section officer. Do the same for a person in your life: Offer him or her an opportunity to volunteer and support our industry.
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ESAB:FP_TEMP  6/6/08  3:05 PM  Page 7
Lloyd’s to Fund Chair in Materials Fabrication and Engineering

The Lloyd’s™ Register Educational Trust recently funded a new chair in Materials Engineering and Fabrication at The Open University, a distance learning institution headquartered in Milton Keynes, UK. The award is for £1.18 million spread over five years. It will support research investigating the structural integrity of welded joints, as well as for developing improved methods for residual stress analysis.

“We are delighted that Lloyd’s Register Educational Trust has selected us for this major award,” said Dr. Michael Fitzpatrick, who leads the structural integrity research activity at The Open University. “It will allow us to boost our work in structural integrity assessment of welded joints, which is already recognized as world-leading.”

Michael Franklin, director of the trust, said, “A large part of the Educational Trust’s work is to support fundamental engineering research to address problems and challenges and to find solutions that will be for the public benefit. In the last few years, we have committed around ($19.6 million) to support research programs at a number of universities around the world. The award to The Open University brings them into this unique and important group.”

The award will complement a broader collaboration on engineering teaching and research between the university and TWI aimed at addressing skills shortages in the engineering workforce.

Laser Mechanisms Relocates Its European Office

Laser Mechanisms, Inc., Farmington Hills, Mich., recently moved its Laser Mech Europe sales offices from Destelbergen to Mariakerke, Belgium. The 2500-sq-ft facility houses sales offices, showroom, training room, meeting room, and an expanded warehouse.

“This relocation allows us to more effectively serve our expanding European customer base with state-of-the-art beam delivery components and laser system solutions,” said Arvi Ramaswami, managing director, Laser Mech Europe.

Laser Mechanisms designs and manufactures laser beam delivery components and articulated arm systems for high-power CO2, YAG, and fiber lasers for numerous industrial applications. For more information, visit www.lasermech.com.

Linde Sells Its Colombian Subsidiary to Chilean Firm

The Linde Group recently sold its Colombian subsidiary, Cryogas S.A., to Indura S.A., the Chilean industrial gases and welding company. The divestiture was an antitrust condition imposed by the Colombian regulatory authorities arising from the 2006 acquisition of The BOC Group plc by Linde.

Cryogas S.A. employs approximately 400 people and achieved sales of about $76 million in the 2007 fiscal year.

Global Market for Welding Equipment and Supplies Worth $16.9 Billion by 2013

The global market for welding equipment and supplies will be worth $13.2 billion by the end of this year and is expected to increase to $16.8 billion by 2013, a compound annual growth rate (CAGR) of 5%, according to a report from BCC Research (www.bccresearch.com).

The market is divided into applications of welding equipment and consumables, welding gases, safety and protective equipment, and welding robots and accessories (Table 1). Of these, welding equipment and consumables has the largest share of the market. Worth an estimated $10.7 billion by the end of the year, this segment should reach $13.6 billion in 2013. This segment is steadily growing since consumables are not only required for new equipment but also for all existing equipment.

The safety and protective equipment segment is also growing steadily as safety regulations are enforced globally.

More industries are automating and robotic welding is becoming a standard feature of such automation. The market for welding robots is growing at a higher rate than any other market for industrial robots. Expected to be worth $108 million this year, this segment should reach $148 million by the end of the study period, for a CAGR of 6.5%.

For more information on the report titled Welding Equipment and Supplies: The Global Market (AVM040B), contact BCC Research, 40 Washington St., Suite 110, Wellesley, Mass.; (866) 285-7215, or editor@bccresearch.com.

Loyalist College to Begin Welding Program

The School of Skills Training at Loyalist College, Belleville, Ont., Canada, will offer a one-year certificate program in welding techniques beginning in September. The program was developed in response to industry’s need for welding professionals.

Students will receive extensive welding theory and hands-on experience in the college’s welding shop. There will be a strong emphasis on safety, and students will learn to create and interpret blueprints as well as develop their skills in math and computer applications. The program will also introduce students to robotic welding and practical experience using the college’s full-size robots.

“The truly exciting part of this new program is the career opportunities that students can anticipate following graduation,” said Tom Malloy, dean of skills training, access and continuing education. “Some may choose to work as welder fabricators, welder fitters, production welders, or millwright welders, while others will become structural plate fitters or welding inspectors. The program is also suited to individuals who are already working within the industrial and agricultural sectors. Welding adds another dimension to the skills they are able to bring to the workplace as employees or within their own businesses. Industry has told us they need welders. Our goal is to prepare our graduates to fill this void.”

<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2013</th>
<th>CAGR% 2008–2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding equipment and consumables</td>
<td>9842</td>
<td>10,219</td>
<td>10,677</td>
<td>13,615</td>
<td>5.0</td>
</tr>
<tr>
<td>Welding gases</td>
<td>1911</td>
<td>1968</td>
<td>2017</td>
<td>2618</td>
<td>5.4</td>
</tr>
<tr>
<td>Safety and protective equipment</td>
<td>367</td>
<td>383</td>
<td>406</td>
<td>487</td>
<td>3.7</td>
</tr>
<tr>
<td>Welding robots and accessories</td>
<td>86</td>
<td>96</td>
<td>108</td>
<td>148</td>
<td>6.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12,206</td>
<td>12,666</td>
<td>13,208</td>
<td>16,868</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Table 1 — Sales and Forecasts of Various Types of Welding Equipment and Consumables through 2013 (in $millions)
“I learned that today’s technology could double my welding production.”

Check out the new welding resource site that shows how companies are increasing up-time, reducing weld cycle time and decreasing spatter clean-up by as much as 60%.

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The aircraft and aerospace industry is making great strides in cost reduction. One aspect of this is utilizing composites in place of aluminum. Another innovation is to build critical parts from the ground up, rather than ordering expensive forgings and castings that have to be machined down to size.

Welding is in the very thick of it on both fronts. Improved processes are being developed to weld carbon fiber composite structures. In the world of “born to shape parts,” innovative welding processes like electron beam, laser, and others are getting the job done efficiently and economically.

September 16-17, 2008
Wichita, Kansas

American Welding Society
At this AWS conference in Wichita, emphasis will be given to friction stir welding, fiber laser welding, and the gas-shielded welding processes. The role of titanium is growing, and the emergence of a number of new aluminum-lithium alloys poses new welding challenges. Ultrasonic welding, a front-runner for the welding of thermoplastic composites, will be on the agenda, as well.

Plans for vehicles to carry humans to the moon by 2010 (and later, to Mars) will also be discussed.
Koike Aronson/Ransome Celebrates 90th Anniversary and Plant Expansion

Koike Aronson/Ransome, Inc., Arcade, N.Y., a designer and manufacturer of welding positioners and thermal cutting products, as well as portable and gas apparatus equipment, recently held an open house on May 16. About 90 attendees showed up.

“I want to thank everybody for coming to help us celebrate not only Koike’s 90th year in business, but the completion of our latest expansion,” said company President and CEO Jerry Leary. He also expressed gratitude to the company’s 172 employees.

After detailing Koike’s history, Leary talked about its challenging times. “From 1985 to 2003, the company did very poorly,” he said. It had an onerous debt along with a deficit, and just 73 employees. “We were literally out of business,” Leary said, but after Labor Day 2003, “some of the things we had put in place started to kick in, and the rest is history.” Since this point, revenues have tripled, and debts and deficits have been eliminated.

The Arcade location grew through many factors. First, management was reorganized at the end of 2002. It purchased Ransome Manufacturing the previous year. Another transformation was how the company sold products; it changed to independent manufacturing representatives in Canada, the United States, and South America. The following also helped: Customer service got restructured; two nonperforming offices were closed; factory efficiencies were improved, leading to good lead and delivery times; distribution policies were restructured; reorganization took place from a traditional format to three business units for cutting machines, positioners, and portable gas apparatuses; a management by objective and incentive system was implemented; new products were added; the portable and gas apparatus sales/inventory moved to Houston, Tex.; and a customer visit program started.

Recent successes have occurred as well. In 2006, Wyoming County, N.Y., honored Koike as the Manufacturer of the Year. In 2007, it received ISO 9001 certification; the first 11,000-sq-ft expansion finished; and the Worldwide Koike Group Presidents Meeting took place for the first time in Arcade. This year, the company has been certified by the state of New York as an Empire Zone, qualifying it for state tax credits in exchange for $11 million in investments at the Arcade location; and moving in the second expansion of 20,000 sq ft started in May.

Koike Sanso Kogyo Co., Ltd., in Japan, is its parent company. Other operations exist in the Netherlands (Koike Europe B.V.), China (Koike Engineering Tangshan Co., Ltd.), and South Korea (Koike Korea Engineering Co., Ltd.).

New goals have been set. “In the next 14 to 18 months, we’re planning a new addition, and that will create more jobs here,” Leary said. The company is creating a line of downdraft and cutting tables in 2008, too.

New York State Senator Dale Volker offered his congratulations. “This turnaround is unbelievable. It shows you what American and Japanese ingenuity can do, and how you can take a business that had major problems and through great management and through intelligence, turn it around,” Volker said. “This is an enormous worldwide operation out of Arcade, N.Y., that’s making Arcade a name throughout the world.” He added, “It’s companies like this that give you great heart.”

Additionally, the day included guided plant tours of the machine, electric, and weld shops; shipping department; and demonstration room. All of the fabrication, welding, and cutting are done in-house. Building of the company’s third 6-kW laser to be made in the United States will take place at this facility. The event ended with a barbecue lunch. — KRISTIN CAMPBELL, associate editor
Welder Training Begins at Iron Workers Center in Utah

The first welding classes at Iron Workers Local 27 Training Facility, West Valley City, Utah, took place April 26. This event represented a goal for Michael L. McDonald, the Local 27 business manager, who wanted this section to have a place of its own. It is hoped American Welding Society accreditation for the Iron Workers National Certification Program will be achieved soon.

“We are proud of our new facility and are excited about our ability to continually improve the quality of the training received by our journeymen and apprentices,” said Bob North, president, Iron Workers Local 27/director of apprenticeship and training.

“We are now in a position to reach our ultimate goal of providing, to our signatory employers, the best trained workforce in our five state jurisdiction.”

A student practices shielded metal arc welding at the new Iron Workers Local 27 Training Facility. This photo also shows the booth set-up complete with an exhaust hood above the welding fixture.

Instructor Todd Anderson (left) is shown teaching Maria Sandness, one of two females currently in the program.
The 7500-sq-ft building houses 23 welding booths and three class-rooms. Training is provided in shielded metal arc, gas tungsten arc, flux cored arc, and gas metal arc welding. Neal Borchert and Jim Truett from Miller Electric Mfg. Co., along with Mike Weaver of Airgas, helped with pricing various types of equipment.

Four instructors, three of whom are Certified Welding Inspectors, teach three hours on Monday and Wednesday evenings, and six hours on Saturday. Students range from apprentices just starting or having some welding experience to journeymen wanting...
to learn or brush up on their techniques; they are all either members of Local 27 or travelers from other local trade organizations. After apprentices finish four years of training, they become journeymen and can make a good living.

In addition, a structure is set up to learn steel erection techniques; a concrete form teaches working on a rebar wall; an ornamental mock-up provides learning on window wall and curtain wall systems; and a preengineered metal building mock-up will be purchased in the near future.

For more information, visit the Iron Workers Web site at www.ironworkers.org or go to www.ironworkers27.com.

College of New Caledonia Receives Nearly $1 Million for New Trades Equipment

The British Columbia Ministry of Advanced Education has approved targeted funding for the College of New Caledonia (CNC) in the amount of $905,375 to purchase new equipment for three existing trades programs. Among the recipients is the welding program with welding machines, feeders, welding tent, forklift, and ironworker cutting devices.

“The new funding will allow our students to learn on the most up-to-date, technologically advanced equipment. It’s essential to allow the college to continue to meet community needs for trades workers throughout the region,” said Lynn Jacques, CNC’s VP Academic.

Senator Barack Obama Visits CMW

CMW Inc., a manufacturer of highly engineered metal alloys and composites used in a broad array of industrial applications,
CMW recently hosted Illinois Senator Barack Obama at its Indiana facility. Pictured (from left) are Jennifer Sniderman, Obama, and Mark Gramelspacher.

Obama enjoyed a recent visit to its Indianapolis, Ind., facility from U.S. Senator and presidential hopeful Barack Obama. Obama toured the company’s operations with Mark Gramelspacher, president of CMW. Also, he met many employees, listened and responded to questions about American manufacturing and his proposed policies, and then conducted a nationally televised town hall meeting with approximately 200 people from the Indianapolis community.

Gramelspacher kicked off this meeting with general comments about the family-owned business. Additionally, he expressed specific concern over one of the major challenges CMW and similar employers face regarding workforce development and hiring qualified people. Obama called CMW “a model of the kind of company that we should be seeing all across America where management and labor are working together for decent wages and decent benefits.”

**Approved Electroslag Welding in Florida Speeds Splicing of Bridge Girder Flanges**

Florida Structural Steel (FSS), Tampa, Fla., sees economic advantages in splicing bridge girder flanges with the new narrow-gap electroslag welding (NG-ESW) technique. According to Dale Ison, manufacturing manager, it cuts welding time for butt-splices of top and bottom flanges by about two-thirds.

The Federal Highway Administration (FHWA) approved the use of NG-ESW in March 2000, rescinding a moratorium imposed in 1977. The technique applies to bridge steel members that are in tension, reversal, or compression, but not fracture-critical steel members or those in geographic Zone 3. Only Texas and Florida have allowed this welding technique for splicing of main members in their bridges.

“Florida Department of Transportation (FDOT) wrote it into their new specifications for Section 460, Structural Steel and Miscellaneous Metals,” said Ison. “Florida Structural Steel is working on ten girder bridges for the Courtney Campbell Causeway interchange, in the vicinity of Tampa International Airport. This project falls under the 460 specifications, so FSS applied to FDOT for, and received, permission to use NG-ESW to butt-splice girder flanges. This interchange project involves ten girder bridges and about 1400 flange butt splices.

“Unfortunately,” said Ison, “we did not qualify for NG-ESW in time to use it on all ten girder bridges in the project. FSS will

---

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For info go to www.aws.org/ad-index
probably use it on six bridges, portions of which have already been erected.” Ison also noted the electroslag equipment came from Arcmatic Corp., Vallejo, Calif.

All the electroslag bridge welds made by FSS undergo 100% ultrasonic and X-ray inspection, as required by the code. “KTA-Tator, Inc., Pittsburgh, Pa., is witnessing the inspections for us,” he noted.

Industry Notes

- Stillwater Technologies, Inc., Troy, Ohio, a contract tooling and machining company and manufacturer of resistance welding consumables and accessories, held an open house on May 17 to celebrate its 50th anniversary. The event was followed by a picnic lunch.
- Del Moerke Jr. and son Steven Moerke have purchased D/F Machine Specialties, Inc., North Mankato, Minn., from the other Moerke family members. For 40 years, the company’s welding products have been used on automatic and robotic gas metal arc and gas tungsten arc welding systems.
- Honeywell, Morris Township, N.J., has acquired Norcross Safety Products LLC, Oak Brook, Ill., a manufacturer of personal protective equipment, for approximately $1.2 billion.
- Pennington Allen Capital Partners LLC, Tulsa, Okla., has completed its investment in Mathey Investments, Inc., a developer and manufacturer of pipe cutting and beveling machines, welding electrodes, and flux ovens.
- Lincoln Electric Holdings, Inc., Cleveland, Ohio, has acquired Electro-Arco, S.A., a privately held manufacturer of welding consumables based near Lisbon, Portugal.
- At the annual Excellence in Industrial Technologies Awards Banquet and Networking Sessions in San Antonio, Tex., Frost & Sullivan honored various companies including ABB Low Voltage Drives, Bohler Welding Group USA, Inc., ESAB Welding & Cutting Products, and Kobelco Welding of America, Inc.
- ITT Corp. has completed the acquisition of Kaliburn Inc., Charleston, S.C., a designer and manufacturer of plasma arc cutting equipment and consumables, through its wholly owned subsidiary Cleveland Motion Controls, Inc., Cleveland, Ohio.
- At the 2008 International Glove Association (IGA) annual meeting in March, the IGA reviewed its 2003–2007 U.S. hand protection market demand study. Industrial glove demand had a 6.5% compound annual growth rate over the study period.
- Clearview Capital, LLC, Old Greenwich, Conn., has completed acquiring Mayo Welding Services, Inc., Berthoud, Colo., as an add-on transaction to Hettinger Welding, LLC.
- AK Steel’s Zanesville (Ohio) Works has been honored with two awards for its safety performance by the Ohio Bureau of Workers’ Compensation, division of Safety and Hygiene.
- Airgas, Inc., Radnor, Pa., has acquired A&N Plant, a European-based supplier of new and reconditioned rotating, positioning, and welding equipment.
- CFD-online, an online center for Computational Fluid Dynamics, has set up a forum for users of Flomerics EFD suite of simulation software at www.cfd-online.com/Forum/cfd.cgi.
- Coghlain Companies Inc. completed acquiring the assets of KEEF, Inc. (doing business as Stonebridge), a Worcester, Mass.-based precision machining and certified welding company.
- The GBC Materials business of Morgan Advanced Ceramics is offering online ordering capabilities at www.gbcmaterials.com/catalog for its VX Super Refractory Crucibles.
- GEA PHE Systems, a international supplier of plate heat exchangers (PHE), has acquired the assets of Canadian PHE specialist ViEX, based in Newmarket near Toronto.
- Aerojet, Sacramento, Calif., has earned The Boeing Co.’s Supplier of the Year Award. It has been the sole supplier to Boeing for the F-22 Raptor welded titanium forward buses.
- Manoir Industries SA, Paris, has entered into an agreement to acquire a 70% stake in Changzhou Shine Science & Technology Co., Ltd., of the People’s Republic of China, a manufacturer of welding safety products.
- Actuant Corp. has completed the purchase of Superior Plant Services LLC in a deal worth $57 million. The acquired company will be managed in part with Hydratight, Red Wing, Minn., one of the businesses comprising Actuant’s Industrial Segment.
- Rankin Industries, Ranch Cucamonga, Calif., has been registered by Intertek Testing Services as conforming to the requirements of ISO 9001:2000. The certification is applicable to its management systems for the design and manufacture of buildup and hardfacing welding products.
- Valley National Gases, LLC, has acquired the gas and welding business of N. H. Bragg & Sons. Also, the company is moving its corporate headquarters to Independence, Ohio.
- The American Iron and Steel Institute is rolling out the Bar Steel Fatigue blog, www.autosteel.org/barfatigueblog, an online tool for automotive engineers.
- Orbitiform Group, Jackson, Mich., recently announced Tool & Assembly Systems, Inc., has joined the company as sales representatives for Ontario.

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: Kristin Campbell
550 NW LeJeune Rd.
Miami, FL 33126.

Items can also be sent via FAX to (305) 443-7404 or by e-mail to kcampbell@aws.org.
Electron Diffusion Inquiry Gets Resolved


My question originates from the first paragraph on page 31 with the sentence stating, “Some electrons in the ionization layer with sufficient energy to overcome the electric field of the space charge layer will diffuse back to the surface of the cathode.”

The electron is negatively charged, the space charge layer is a “cloud” of negatively charged electrons, and the cathode is negatively charged so the polarity of the space charge layer and the cathode would repel the electron.

Why would an electron diffuse back through the space charge layer to the cathode? It seems that it should be repelled.

Dale Flood
AWS District 22 Director
Project Manager, R&D for
TRI TOOL INC.
El Dorado Hills, Calif.

The explanation of the electron back diffusion is tied to the microscopic description of the fluid (kinetic theory). In this case, the fluid in front of the electrode is made of electrons, atoms, molecules, ions, photons; each possessing a velocity vector. Due to the large number of particles involved (for example, the number density of air at atmospheric pressure is $10^{25} \text{m}^{-3}$), it is impossible to track them all. Therefore, one uses statistical distributions to describe the number of particles with a given velocity vector. Thus, statistically, there will always be a certain number of particles moving toward the cathode. Some will have high enough speeds to overcome the repelling force of the electric field (an analogy can be made with a rocket escaping the earth’s gravity). Please note that this description of the near cathode zone is a model that aims at explaining the transition from the solid cathode to the plasma arc column. Model calculations show that the back diffusion electrons represent less than 1% of the total current (emitted electrons, ions, and back diffusion electrons).

Nakhleh Hussary and Thierry Renault,
Thermal Dynamics

Dear Readers:

The Welding Journal encourages an exchange of ideas through letters to the editor. Please send your letters to the Welding Journal Dept., 550 NW LeJeune Rd., Miami, FL 33126. You can also reach us by FAX at (305) 443-7404 or by sending an e-mail to Kristin Campbell at kcampbell@aws.org.

For info go to www.aws.org/ad-index
Q: We are trying to fabricate a number of AL6XN vessels (3/8-in. wall thickness) using 1/16-in. Alloy 625 filler metal by submerged arc welding. This is the recommended filler metal, but we are fairly often getting centerline cracks in the root pass. When that happens, we have to gouge out the cracks and repair with matching covered electrodes. This costs a lot of time and money. The covered electrode repairs never crack. Then we can successfully finish the joint with submerged arc. The welders suggest that we use covered electrodes for the root pass to begin with, then finish with submerged arc. An entire root pass with covered electrodes is expensive. What can we do to make successful submerged arc root passes?

A: AL6XN is a trade name for the super-austenitic stainless steel whose composition is given by UNS Number N08367. Alloy 625 is a common name given to the

| Alloy          | % C | % Mn | % P | % S | % Si | % Cr | % Ni | % Mo | % N | % Cu | % Nb | % W | % Fe |
|---------------|-----|------|-----|-----|------|------|------|------|-----|-----|------|-----|-----|-----|
| AL6XN N08367  | 0.030 | 2.00 | 0.040 | 0.030 | 1.00 | 20.0 to 23.5 to 6.0 to 0.18 to 0.75 | max | max | — | — | Rem. |
| Alloy 625 ERNiCrMo-3 (Ni 6625) | 0.10 | 0.50 | 0.02 | 0.015 | 0.50 | 20.0 to 58.0 | 8.0 to 10.0 | max | 0.50 | 3.15 to 4.15 | max | 5.0 |
| Alloy 22 ERNiCrMo-10 (Ni 6022) | 0.015 | 0.50 | 0.02 | 0.010 | 0.08 | 20.0 to 22.5 | 14.5 | max | 0.50 | 2.5 to 3.5 | 2.0 to 6.0 |
| Alloy 276 ERNiCrMo-4 (Ni 6276) | 0.02 | 1.00 | 0.04 | 0.03 | 0.08 | 14.5 to 16.5 | Rem. | 15.0 to 17.0 | 0.50 | 3.0 to 4.5 | 4.0 to 7.0 |
A pretty good rule of thumb in estimating resistance to solidification cracking is that no niobium is good and a lot of niobium is dangerous. That is where dilution enters the picture. Welding with covered electrodes is pretty much limited to 30 to 35% dilution under most circumstances, so that the root pass made with ENiCrMo-3 SMAW electrodes in AL6XN base metal will contain more than 2% Nb, and will be resistant to solidification cracking. However, submerged arc welding often produces 40 to 50% dilution, or even more. Fifty-percent dilution drops the root pass niobium content to about 1.5%, and that is dangerous as regards solidification cracking. This problem is not unique to welding of 6% Mo superaustenitic stainless steels — it is well known also in the welding of 9% Ni steels with ENiCrMo-3 filler metal for liquid natural gas containment where root pass solidification cracking tends to occur in submerged arc welds.

You can take steps in welding the root pass to limit dilution. Welding the root pass with DCEN polarity instead of the more common DCEP polarity is a good way to limit dilution, although it often produces a convex bead shape that some find objectionable. Welding with longer electrode extension can reduce dilution, but it tends to have problems with consistent bead placement (wire wander). Reducing welding current (by reducing wire feed speed) can also reduce dilution, but that reduces productivity as well.

Perhaps a better solution is to change filler metals to one that meets the overlapping molybdenum requirement but contains no niobium. The most common choice in this regard is Alloy 22, AWS A5.14 Class ERNiCrMo-10 or ISO 18274 Class Ni 6022. This filler metal, whose composition range is included in Table 1, is niobium-free. Therefore, it tolerates a wide range of dilution possibilities in SAW with minimal risk of solidification cracking. I assume that you have been using a high-basictity flux for SAW, as these are the only flux types that work well with ERNiCrMo-3 filler metal. If so, the same flux should work well with the ENiCrMo-10 filler metal — in fact, without niobium in the filler metal, you are likely to encounter better slag removal than you experienced with the ERNiCrMo-3 filler metal.

Alloy 276 (AWS A5.14 Class ERNiCrMo-4 or ISO Class Ni 6276) is also a possible selection for filler metal. It too is niobium-free, as can be seen in Table 1. Its welding characteristics are very similar to those of Alloy 22. Your choice between these two filler metals, should you decide to follow the Nb-free approach, can be based on cost and availability.

**DAMIAN J. KOTECKI** is president, Damian Kotecki Welding Consultants, Inc. He is a past president of the American Welding Society, a past vice president of the International Institute of Welding, and a member of the AWS ASD Subcommittee on Stainless Steel Filler Metals, and the AWS D1K Subcommittee on Stainless Steel Structural Welding. He is a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel-Based Alloys. Send your questions to Dr. Kotecki at damian@damiankotecki.com, or to Damian Kotecki, c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126.
This roundup of advancements in the world of cutting will include such processes as oxyfuel cutting, plasma arc cutting, laser cutting, and water jet cutting. A great deal is happening in computerization. Cuts are far more precise, more repeatable, more accurate, and much faster than ever before. Accompanying the improvements in machines and controls are improvements in torches, consumables and cutting heads. A presentation will weigh the relative merits of the many fuel gases that can be put to work on oxyfuel cutting lines. This conference demonstrates that we have entered a new era in thermal cutting. To register or to receive a descriptive brochure, call (800) 443-9353 ext. 455 (outside North America, call 305-443-9353), or visit www.aws.org/conferences
NEW TECHNOLOGIES IN THERMAL CUTTING CONFERENCE
Monday, October 6, 2008 • 8:50 AM – 4:05 PM
Las Vegas Convention Center
Member of AWS, FMA, SME, NAM, or PMA: $345
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Quality Flame Cutting After 107 Years
John Dawson, Consultant, ESAB Cutting Systems, Florence, SC
A century of advances in flame cutting shows what the past can teach us about the latest technologies and applications.

State-of-the-Art of Mechanized Plasma Cutting Technology,
James Colt, Strategic Accounts Manager, Hypertherm Inc., Hanover, NH
Mechanized plasma arc cutting has been commercially used since the early 1960’s for a variety of applications. Plasma has always had a reputation as the “Productivity Process” due to its ability to cut a wide range of materials and thicknesses at high speeds. Advancements in the last ten years have further developed plasma into a more refined process that provides dramatically higher cut part accuracy, high cutting speeds, full automation capability….all at a lower cost per foot of cut.

Introduction to Industrial Lasers
Lou Derango, 2D Product Manager, Mazak Optonics Corp., Schaumburg, IL
An introduction to basic laser workings and considerations with follow-up in a few typical metal applications. This presentation is meant to be a primer for those interested in pursuing laser technologies. The follow-up of the presentation will include a few samples of laser processing quality with question and answer period.

Computerized Pipe and Tube Cutting
Jim Blackburn, General Manager, Vernon Tool Co., a Business of Lincoln Electric Co., Oceanside, CA
Using a Powerpoint presentation, the speaker will discuss current pipe cutting methods with attendant efficiencies. Specific industries dictate different machine configurations, computer controls, and cutting methods. Recommendations for designing an efficient “burn rack” will be disclosed.

The speaker will also address improvements in mechanized cutting machines, material handling alternatives and CAD-CAM data flow from popular isometric and structural modeling software. Machine operations and features are a guide to effective, efficient shop production and labor saving opportunities. Thirty-five years of management provide historical perspective of machine evolution; from simple gear-driven machines to 6-axis CAD-CAM driven work cells.

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How Nesting Solutions Develop a Positive Impact on Thermal Cutting Processes
Marius Pienaar, Director, SigmaTEK Services, Cincinnati, OH
This particular CAD/CAM software is designed to achieve the following: integration for scheduling, estimating, engineering and costing; improved part quality; improved utilization of materials; and improved cutting flow.

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Waterjet Systems Can Cut a Wide Variety of Materials
Wiktor Stepień, Vice President-Sales, and Bob Pedrazas, Marketing Manager, KMT Waterjet Systems, Baxter Springs, KS
Waterjet cutting systems are able to cut virtually any material. Waterjet machining offers many advantages compared to other technologies, including colder cutting, increased precision, and a greater variety of applications. This presentation will be centered on the use of waterjet cutting applications for flat stock metals (aluminum, stainless steel), ceramics, stone, plastics, and composites for the aerospace, automotive, job shops, electronic, stone, glass, and metal industries. Video examples will be included within the presentation to demonstrate how waterjet technology can help improve the quality, speed and efficiency of these manufactured products.

Innovative CNC Control on State-of-the-Art Plasma Shape Cutting Technology
Mark Osowski, Product Manager, Burny/AMC Business Unit, ITT Cleveland Motion Controls, Cleveland, OH
Innovative features developed in Burny CNC controls are tightly coupled to Kaliburn plasma systems to create a fully automatic shape-cutting motion control process. This talk will detail how ITT Cleveland Motion Controls is striving for new technology that takes the waste, both in time and material, out of the shape-cutting process. Learn how you can save on labor and operating expenses in your plasma application.

Fuel Gases, Piping, and a Little OSHA
John Dawson, President, Thermal Cutting Consulting Inc., Florence, SC
The decision as to which fuel gas to use in a specific cutting operation is not always an easy one. The choice is extensive. It includes acetylene, propane, natural gas, propylene, MAPP, LPG, etc. However, the appropriate choice can be made based on the best performance/cost ratio. In addition, users of fuel gases who have them piped into their plants are facing problems with certain OSHA regulations. This situation will be explained.

The Use of CAD/CAM Software to Program Robots to Cut Structural Steel and Pipe
Chris Anderson, Technology Leader-Welding, Motoman, W. Carrollton, OH
Typically, robots are programmed manually with teach pendants creating point to point programs. Offline programming is done in a similar fashion, but in a virtual environment. Cutting machines use CAD/CAM software to generate shapes and often automate programming tasks such as nesting multiple shapes in an optimized pattern on a sheet. Utilizing a conversion routine, these shape-patterns can be converted to robot programs without the use of traditional programming methods. This allows paths from CAD software such as AutoCad to be converted into cut paths. Cut paths can also be created from G-code generated out of CAM software. Robotics brings the advantage of 6 degrees of freedom for positioning so beveling and contours can be cut on 3D parts such as structural shapes and pipe.

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NEW PRODUCTS

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The 3M™ Speedglas™ 9100 welding helmet and autodarkening filter series replaces the Speedglas 9000 series. The helmet’s pivot point is located just above the welder’s ears. The cradle design of the head suspension, combined with the headband’s self-adjusting boogie/twin pads, more closely profiles the true shape of the user’s head. The helmet also has a smoother up-and-down pivot action that gently locks in the up position. In addition, the head suspension system provides several adjustment combinations — back-and-forth, higher-and-lower, and tilt — so welders can fit the helmet to their personal preferences. The seven dark shade settings are as follows: Shade 5 (for gas welding/cutting), Shade 8 (for microplasma and low-amp GTAW), and Shades 9–13 for most arc welding processes. The welding filter series V, X, and XX have normal, large, and extra-large viewing areas, respectively.

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The Power Wave® AC/DC 1000 inverter power source is designed as part of a modular welding system for single or multiple arc applications targeted at submerged arc users who want to increase productivity and have greater production flexibility. The machine is rated at 1000 A for AC or DC. Each welding arc may be driven by a single machine or a number of machines in parallel. It produces a variable AC output as well as straight DC positive or negative output. The product also uses the company’s Nextweld® Waveform Control Technology®. The AC waveform can be set to any frequency between 0 and 200 Hz. Plus, parameters can be controlled and regulated automatically so synergic adjustments can be made by the machine while welding.

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Low-Hydrogen Covered Electrode Minimizes Cracking and Spatter

For general purpose, low-hydrogen welding applications, the Hobart® 418...
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The Qualitek mR, a single-channel tester designed for high-volume industrial leak and flow testing applications, combines advances in multi-range (mR) testing technology. It inspects gas control valves, plastic reservoirs, packaging, and other applications. Two transducer inputs allow the tester to accept pressure decay, differential pressure, mass flow, and load cell transducers. A touch-screen color graphics display and PC-style menus, in combination with a rotary scroll and click navigation device, make setup and testing easy. It also features built-in pressure plots and statistics, data storage, compensation and calibration, and a pop up soft keyboard to facilitate program editing.

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The Stoody® 300 series flux cored wire offers high-quality weld deposit, an environmentally friendly wire basket, and good feedability to reduce downtime. The random wound wire provides a higher deposition rate. The product is stocked in sizes 308L, 309L, and 316L; and in both flat/horizontal and all-position welding grades.

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**Capacitive Discharge Welding Machine Features Improved Productivity**

The 1000Ws Advanced Dual Pulse welding machine provides improved productivity and weld consistency. The unit includes a user interface incorporating a 6.5-in. high-resolution color display. It also comes in 100Ws and 300Ws versions. The peak current for pulse 1 and 2 can be monitored, and limits set for each with the option of second pulse inhibit. An up-slope function can be programmed on the pulse to gradually increase the weld energy to alleviate weld splash. The programmable polarity function makes it possible to individually select the polarity of pulse 1 and 2, or have alternating polarity for successive welds. What's more, the four pulse durations are spread more evenly to offer an increased range of weldable materials and parts.

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Six torch packages include all of the components necessary for GTAW. Four
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The Millermatic® 180 with Auto-Set™ runs off 230 V, giving the user the capability to weld from 24 gauge up to ⅛-in. mild steel in a single pass. Auto-Set is designed to work on mild steel using C25 gas (75% argon, 25% CO₂). Just select the wire diameter (0.023 or 0.030 in.); set the machine to the material thickness being welded (the company provides a free material thickness gauge to check it with); and start welding. The machine is automatically set to the proper voltage and wire feed speed for the job. An accessory is Miller’s Spoolmate™ 100 Series spool gun. Hooked up to this machine, the series can weld from 18 gauge through ⅛-in. aluminum.

**Miller Electric Mfg. Co.**

www.MillerWelds.com

(920) 734-9821

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**Preengineered Welding Cell Offers Flexibility**

The PA-55 preengineered Perform-Arc welding cell can accept a payload of up to 250 lb per side and welds typical part sizes that include 12 × 53, 18 × 45, and 24 × 30 in. A platen design provides repeatable fixture locating when multiple fixtures are to be exchanged on the same work cell. It
comes standard with a Panasonic 6-axis robot, an inverter welding machine with artificially intelligent waveform control, and a torch. Full system controls, diagnostics, and programming capabilities are managed by the color teach pendant, running Windows CE to flatten the learning curve.

Panasonic Factory Solutions Co. of America
www.panasonicfa.com
(847) 495-6100

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The company offers MAP//PRO™ gas as a new fuel for the manual cutting industry. The introduction comes after the announcement that the sole North American manufacturer of MAPP® gas will no longer produce this gas as it is closing its Canadian operations. MAP//PRO, produced by Worthington Cylinders, has a higher flame temperature and better combustion intensity than propane. It also has a higher vapor pressure than MAPP, resulting in better performance in colder temperatures.

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Packaging for Productivity

While packaging may be an easily overlooked area of the welding operation, it can positively contribute to a company’s overall efficiency

BY IVAN MITCHELL

Fig. 1 — Filler metals come in a variety of sizes, styles, and weights; choosing the right packaging can reduce downtime for changeover.

When a company improves its productivity, it automatically impacts its bottom line — positively. In recent years, the emergence of lean manufacturing trends and improved welding processes have supported that goal across many industries. Faster, more efficient workflow simply creates greater throughput.

Not surprisingly, when a company looks at its overall welding process, power sources are often the top consideration to help improve productivity, as well they should be. The right power source for the application can make a measurable difference in the speed and quality of welding. So too can the right filler metal — a metal cored wire process, for example, certainly completes the job faster than a shielded metal arc electrode.

But what about the right filler metal (specifically, welding wire) packaging? This too is an important but frequently overlooked aspect of the welding process.

Yet choosing and using the right size, style, and weight of filler metal packaging, along with implementing good storage practices, can contribute meaningfully to a company’s overall efficiency — Fig. 1.

First, the proper filler metal packaging can reduce downtime for changeover — all time spent moving a package off the line, retrieving another, and readying it for welding takes away from production. The right package can also help ensure that labor is allocated for value-added activities, or those activities that contribute to the overall throughput. Proper storage of packaging further supports good welding wire performance, which in turn can minimize timely and costly rework that takes away from production.

Here are a few packaging factors that in conjunction with the right equipment, appropriate welding wire, and good lean manufacturing and fabricating practices can aid in improving a company’s overall productivity. Remember, the impact filler metal packaging has on productivity may not be immediate, but it can make a difference over the course of time.

Less Changeover and Waste = More Arc-On Time

Most types of filler metals — for the sake of this discussion, welding wires (solid, flux cored, and metal cored) — are available in a variety of styles and weights. Most range from as small as 15-lb spools to as large as 60-lb coils and 900- or 1000-lb drums.

The first consideration when choosing the right packaging is whether the welding operation is inside or outside. For outside construction, shipbuilding, or general field welding applications, portability is key in maintaining good productivity; dragging a large filler metal package around is simply not feasible. It takes too much time and labor. Instead, a 15-lb spool would be appropriate.

In a one to two person (indoor) shop where the weekly volume of welding wire usage falls into the 150- to 200-lb range,

IVAN MITCHELL is application engineering specialist, Hobart Brothers, Troy, Ohio, www.hobartbrothers.com.
The filler metal package should also be in a place where it is not in the way of moving equipment, such as forklifts, that can damage it. Damaged packages can cause unnecessary downtime for changeout, and this damage can also void the warranties provided by filler metal manufacturers. Not only does a company run the risk of downtime and increased labor for replacing the package, but it could also incur additional cost for new wires. Drums, spools, and reels should not be double-stacked for the same reason. Stacking can damage the wire, and it can also be dangerous to welding operators who should store the reel or drum in a designated location. There should always be enough packages of filler metal in storage to prevent a production stoppage. Also, companies should rotate stock to ensure that no packaging sits in storage for an extended period of time; those filler metals delivered first should be used first to gain the best welding performance.

Upon arrival, the filler metal package should be placed in an area that is easily accessible when changeover is necessary. Excessive downtime can occur if a welding operator has to go a far distance to acquire another package and that again takes valuable time away from the weld cell.

Likewise, proper storage of filler metal packages helps ensure top performance from the filler metal and can help companies avoid unnecessary rework — welding operators can contribute to a product’s throughput rather than spend time repairing mistakes. As a rule, until the package is opened it should be stored in a dry, well-ventilated place to protect against moisture, the number-one culprit of welding wire damage. Additional storage information recommended by the filler metal manufacturer should always be followed.

### Make an Assessment

Packaging may be an easily overlooked area of the welding operation, but it can positively contribute to a company’s overall efficiency. Companies that experience excessive downtime for package changeover, have high waste disposal costs or increased labor for package disposal, or those that simply are looking to increase throughput and their bottom line may want to look at their current packaging. Filler metal manufacturers or a trusted welding distributor can provide audits to help companies determine which is the best option for their welding wire — to help improve workflow and increase productivity.

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**Table 1 — Package Change Cost Analyzer**

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>900-lb Drum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Annual Usage (lb)</td>
<td>1,000,000</td>
<td>900</td>
</tr>
<tr>
<td>Package Weight</td>
<td>400</td>
<td>900</td>
</tr>
<tr>
<td>Minutes to Change</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Labor Cost</td>
<td>$20</td>
<td>$20</td>
</tr>
<tr>
<td>Overhead Cost</td>
<td>$30</td>
<td>$30</td>
</tr>
<tr>
<td>Cost per Change</td>
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<td>$25</td>
</tr>
<tr>
<td>Number of Changes per Month</td>
<td>208.3</td>
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</tr>
<tr>
<td>Number of Changes per Year</td>
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<td>1111.1</td>
</tr>
<tr>
<td>Cost of Changes per Month</td>
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<td>$2314.81</td>
</tr>
<tr>
<td>Cost of Drum</td>
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<td>$27,777.78</td>
</tr>
<tr>
<td>Monthly Cost Savings of 900-lb Drum</td>
<td>$2893.52</td>
<td>$34,722.22</td>
</tr>
<tr>
<td>Yearly Cost Savings of 900-lb Drum</td>
<td>$27,777.78</td>
<td>$34,722.22</td>
</tr>
</tbody>
</table>

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**Stay Close, Follow the Rules**

Where and how a company places its filler metal package, while it is in use or in storage, can also contribute to the overall efficiency and productivity of its welding operation.

The package, whether a spool, reel, or drum, needs to easily fit into the allotted footprint in a weld cell lest extra time be spent trying to maneuver it into the area. Ideally, it should take up as little space as possible. In high-volume production facilities, placing two drums on a mezzanine, for example, may be the most appropriate place and the easiest to aid in good workflow, another factor that contributes to improved productivity. When one drum is empty, the spare one can be engaged and the next spare can be added during a nonproduction time.

The filler metal package should also be in a place where it is not in the way of moving equipment, such as forklifts, that can damage it. Damaged packages can cause unnecessary downtime for changeout, and this damage can also void the warranties provided by filler metal manufacturers. Not only does a company run the risk of downtime and increased labor for replacing the package, but it could also incur additional cost for new wires. Drums, spools, and reels should not be double-stacked for the same reason. Stacking can damage the wire, and it can also be dangerous to welding operators who should store the reel or drum in a designated location. There should always be enough packages of filler metal in storage to prevent a production stoppage. Also, companies should rotate stock to ensure that no packaging sits in storage for an extended period of time; those filler metals delivered first should be used first to gain the best welding performance.

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33-lb spools can help minimize changeover (as compared to a 15-lb spool, for example) and would be appropriate to the volume of products welded. Conversely, a 15-person shop that currently uses 33-lb spools would in all likelihood use these spools in one day. Moving to 60-lb coils here could minimize the changeover to once every two days and allow for more arc-on time.

These situations are relatively straightforward: Use a smaller package for smaller volume production and increase incrementally according to the number of welding operators to minimize downtime for changeover and aid in greater productivity. However, when a welding operation has more welding operators or an automated system and greater throughput is desired, choosing the right packaging becomes a little more complicated. Fortunately, the option to minimize downtime and costs, and improve productivity by going to a larger package usually becomes more practical.

For instance, a company that employs robotics or hard fixture automation in its facility would obviously require a greater volume of welding wire in a larger package to meet its production goals than a 15-man shop. How large is the question.

In many cases, 400- or 600-lb drums work well in high-volume, automated welding operations. Consider a company that uses a million pounds of welding wire per year paid out in 400-lb drums. It would require approximately 208 changes per month, or 2496 changes in a year.

The filler metal package should also

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**WELDING JOURNAL**
Save Time and Money with Resistance Welding Simulation Software

Software takes into account various strengths and limitations of welding processes and materials to predict optimum welding conditions and joint design

BY KEVIN R. CHAN

Significant time and money can be saved with the use of software that simulates the process of resistance welding. This article provides specific examples of how this has been done with the finite element modeling software called Sorpas®. This software has been used to assist in the design of resistance welding parts and joints. It determines welding parameters, how the welding parameters can be optimized for various conditions in production, and forecasts the microstructure of the parts after welding.

This software is currently in use by major automotive and manufacturing companies such as GM, Ford, Honda, Volkswagen, Chrysler, Mercedes Benz, Volvo, Peugeot, Citroën, Bosch, Siemens, and ARO. These and other companies use the software to reduce time and money in resistance welding, from the design stage to production floor.

Market Challenges

Clearly, there is an imperative to reduce costs and the “time to market” in an age of increasing globalization and competition. At the same time, many new steels that are both stronger and lighter are increasingly being employed to raise fuel economy and to provide greater crash protection. These driving forces of change and improvement bring problems of increased design and welding complexity when these steels are used.

KEVIN R. CHAN is with Huys Welding Strategies, Weston, Ont., Canada.

Resistance Welding

Resistance welding is an inexpensive process that requires no shielding gases or filler metals to create a metallurgical fusion bond. An electric current is passed through the metals to be welded after a force is applied, and their innate resistance to the current generates sufficient heat to create the weldment. This is shown in four basic steps in Fig. 1.

How Simulation Works

The software uses the power of modern microprocessors to fully articulate all the variables in resistance welding. It does this by considering and calculating all the variables through four separate yet fully coupled models: 1) the electrical model, with its current/voltage distribution and heat generation; 2) the thermal model, with its heat transfer and temperature distribution; 3) the metallurgical model, with its temperature-dependent properties and phase transformation characteristics; and 4) the mechanical model with its deformation, stress and strain distribution in the contact areas, electrodes, and geometries of the workpieces (Ref. 1). Each calculation or iteration involves the use of all four models as shown in Fig. 2.

The operator enters into the computer the geometry of the parts, identity of the materials to be welded, the interface conditions, and the electrodes employed. In another window, the user enters the welding parameters to be used, such as force, time, and current. The user can also ask the computer to generate the required welding parameters, and automatically or manually alter the extent of accuracy sought and the overall simulation controls. When instructed, the computer generates welding parameters, welding lobes, and optimizations, based upon the instructions it has received. All input vari-

Fig. 1 — The basics of the resistance welding process.
ables are kept in common welding parameters and terminology. In Fig. 3, an example of one of the printouts available, which provides a summary of the simulation, is shown. Other reports include real-time animations of the simulated weld, showing such data as deformation and heat and strain distributions.

**Design Stage**

In the design phase, the characteristics and limitations of various joining processes and materials are weighed and selections made. Engineers consider the parts, their design, and how they might fit together. Today, especially in the automotive sector, with our future oil supplies uncertain, more and more attention is being applied to thinner and stronger alloys to take a larger role in manufacturing. Generally, all of this analysis has to be done more quickly than in the past.

Detailed below are examples of how Volkswagen, a manufacturer of micro welded parts, and Honda saved time and money at the design stage by using this simulation software. They used it to visualize the inner workings of the welding process, thereby reducing testing and costs, while at the same time optimizing the welding parameters for long-term performance and quality.

**Simulating Projection Welding at Volkswagen**

Volkswagen’s patents governing *Resistance Welding with Additional Elements* was achieved with the software (Ref. 2). These patents can cover welds in dissimilar metals where additional material is inserted at the faying surfaces.

The software was able to reduce the testing of their hypotheses by simulating projection welding that acts in a similar fashion to their “additional elements.” Volkswagen believed it would be very time consuming and expensive to consider the influences of heat, force, and current on the myriad different materials considered for this process (Ref. 3). The software was able to significantly reduce and focus the testing window. Volkswagen’s drawings (Fig. 4) illustrate how modeling and simulation of projection welding helped achieve production welding parameters for its innovative process.

Other companies have used the software to help design the actual part used in production (Ref. 4). In the drawings (Fig. 5), it can be seen how one company has used different designs of insulation (blue) in the part (on the left) to generate different weld characteristics after simulation (on the right). Modeling and simulation of the differing part configurations were able to show the differences in how the heat was generated in the parts and, subsequently, how the weld initiated and grew. Therefore, the engineer could choose which design looks the most promising and pursue it with additional testing. The simulations can greatly decrease the time to market, while at the same time cre-
ating a paper trail where choices made are appropriately documented, with their accompanying result noted.

**Reducing Test Requirements at Honda**

Honda used the software to reduce the number of tests needed to find an inexpensive way to join the hem of an exterior car door and its inner panel without marking the outer surface. The software was used to aid in the optimization of welding parameters and projection design for an indirect hem projection weld (Ref. 5).

In this case, physically prototyping the many different configurations and testing the actual parts was not economically sound. Without simulation, the choices available for welding parameters of a hem projection indirect weld are daunting and perhaps unmanageable with the newer coated steel alloys. However, the software was able to reconfigure the electrodes and tools to accommodate any resistance heating process. Figures 6 and 7 show Honda’s design. The software accurately estimated the effect of different welding parameters and projection nipple heights that would produce an indent-free outer surface. This was possible by running a series of simulations with certain variables altered.

**Anticipating New Materials**

The performance characteristics of some new TRIP and DP steels alter when they are welded. When these new complex phase steels are made, their strength and character arise from the unique microstructure resulting from controlled cooling and heating. The fusion nugget and heat-affected zone present a temper-

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**Fig. 4** — Illustrations of Volkswagen’s patents for Resistance Welding with Additional Elements.

**Fig. 5** — Example of using different insulation designs (left) to generate different welding characteristics.

**Fig. 6** — Geometric mesh generated by the software for finite element modeling.

**Fig. 7** — A finished simulation illustrating a specific combination of welding parameters and projection designs.
ature range from melting to slight warming around the weld area. This temperature history destroys the carefully created microstructure that gave rise to the steel’s character in the first place and can also lead to other problems such as hardening and cracking. The cooling rate of an advanced steel is often critical to its performance and microstructure. Another issue may be that there is a DP steel welded to a high-strength low-alloy (HSLA) steel, creating a weldment with an unknown mixture of two alloys in the weld.

Thus the cooling rate of a weld in an advanced high-strength steel may adversely affect the performance of that steel in a crash. With these types of issues in mind, the University of Waterloo is working with Sorpas® to predict the microstructure, and hence the performance, of a weld in simulation (Ref. 6).

Figure 8 is an amalgamation of a metallographic photograph of a weld performed in the university on the left which has then been compared to the earlier simulation on the right to confirm its reliability. Dotted lines indicate the overall accuracy of the simulation. Certain nodal points in the simulation are indicated on the drawing, and the simulation indicates their peak temperature (far right).

These peak temperatures are then generated as graphs (Fig. 9), which indicate the coarse zone of the HAZ, the fusion zone, and the intercritical HAZ. Then they are referenced to published constant cooling diagrams (CCT), a copy of one which is reproduced in Fig. 10. Colored dots on the CCT in Fig. 10 tie into the colors on Figs. 8 and 9, indicating the various regions of the weld, based upon peak temperature. It is noteworthy that the simulated peak temperatures of the weld tie into the CCT diagram and the metallographic photographic record of the weld.

**Production Stage**

Described above is how this software can help reduce time and money spent in the design and prototyping stages of new products and new materials. The greatest use, however, has proved to be in the day-to-day use of the software as an aid to increasing stable and consistent production and the optimization of welding parameters.

As an example, take the parts in Figs. 8–10. Let us suppose that we want to change the peak temperature of the weldment and thus control its cooling rate. The software can predict changes in the resultant microstructure with changes in the length of heat or numbers of pulsed heat inputs. Figure 11 shows results from simulation for the temperature history in the coarse-grained HAZ and the resultant changes to peak temperature and cooling rate based upon increments in weld time of a second weld pulse. Thus it becomes easy to adjust and document changes and improvements in a production setting (Ref. 7).

The production environment is primarily concerned with optimizing welding parameters and to maximize and stabilize production. Optimization is an ongoing process, as parts will have variances in their fit and setup, and the materials themselves will vary both in their surface preparation, cleanliness, and appearance as well as in the materials from which they are made (Ref. 8). Therefore, it is every engineer’s desire that he or she can find the best spot in the weldability lobe to gain that overall consistency.
Automotive Parts Supplier Optimizes Welding Variables

As an example, a North American Tier 1 automotive supplier that is currently welding a new line with DP600 steel found that its initial welding lobes were very narrow and that the welding heat was too high, which caused not only shorter electrode life but also transformer duty cycle issues. In addition, the company had limited time and resources to deal with problems of poor quality welds, inspection, and repair (Ref. 9).

The software has a function to automatically generate weld current optimizations based upon a requested size of weld nugget. Complete weldability lobes are calculated in accordance with ISO 14327:2004. The weldability lobe generated by the software has solid colors indicating risk of expulsion while also indicating the nugget size. It also indicates nugget width at the convergence of the weld time and weld current. Purple indicates electrode melting, red shows expulsion at the interface between sheets, green for welds, and gray for no welds — Fig. 12.

The generation of these weldability lobes was then used as an initial guide to set individual welding machines. It was found that the simulations were, on average, 90% accurate. The company also adopted titanium-carbide metal matrix composite coated electrodes, which were found to have a wider welding lobe than uncoated Class 2 electrodes. The company believes that it has saved $100,000 with the simulation software. The savings came from the following:

1) reduced costs with fewer tests,
2) reduced scrap and wasted time,
3) reduced costs for production maintenance problems,
4) reduced time to respond to OEM requirements,
5) reduced time for production running, settings determination, and optimization,
6) improved weld quality and production stability, and
7) fewer problems and misunderstandings and more accurate and documented procedures.

Conclusions

This simulation software for resistance welding, in the hands of a qualified engineer, can significantly reduce the time and expenses of developing new designs and materials, establish better process parameter settings, and improve troubleshooting and weld quality.

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9. Scotchmer, N. 2005. Widening the welding lobe in the RSW process of advanced high strength steels, BAM.
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“...it is very important that we continue to offer new products. New products can take days, weeks and even years to fully develop and test before they can be released to the marketplace. The new Auto-Cut and Ultra-Cut plasma systems from Thermal Dynamics are products we feel are an advantage for us to market. In early 2007, Koike Aronson decided to investigate these products after numerous requests from our distributors and customers. After several months of testing and training we were ready to take the Thermal Dynamics products to market.

We found that we could offer a well built alternative for the customer looking to cut stainless and aluminum with minimal cut angle, acceptable cut surfaces and no dross. And, we found the systems to be reliable, easily mounted to our existing equipment and user friendly.

Thermal Dynamics, backed by Thermadyne technical and product support, has been outstanding. Prompt delivery has allowed us to operate under just-in-time conditions. This is a big plus when storage space is limited due to a large backlog of orders.”

Brad Williams
Koike Aronson, Inc.
National Sales Manager

For info go to www.aws.org/ad-index
Improved Pulsed Gas Metal Arc Welding Nets Higher Productivity

Of all the recent advances in welding technology, some of the most exciting and beneficial are in the area of pulsed gas metal arc welding (GMAW-P). In GMAW-P, as the name implies, the welding current transitions or “pulses” between a high peak current, where metal transfer occurs, to a low background current, which maintains the arc but allows the pool to cool — Fig. 1. This creates a welding capability with increased deposition rates and decreased spatter.

Good applications for GMAW-P include those prone to such problems as incomplete fusion, warpage, melt-through, spatter, lack of pool control, and poor bead appearance. It really shines on thin materials, aluminum, and highly alloyed metals where precise heat control prevents melt-through or metal dilution. In many cases, it can replace gas tungsten arc welding (GTAW) yet provide a similar appearance, while providing the faster travel speeds and decreased training time associated with gas metal arc welding (GMAW).

Unfortunately, many of those who tried GMAW-P in the 1990s dismissed the process as too complex — and it was — often requiring a welding engineer to make it work. That has changed.

GMAW-P has now become accessible for most companies, with solutions available from out-of-the-box, all-in-one machines for small fabricating shops to multi-GMA process systems with programs optimized for mass production or more specialized applications, such as pipe fabrication and power plant construction.

Additionally, the complex interface of yesterday has been replaced by much simpler interfaces. Today’s welding operator only needs to know a wire type, size, gas, and preferred arc setting, and then adjust wire feed speed to weld different thicknesses. This synergic or “one-knob” control, along with the ability to maintain arc length regardless of electrode extension,

CHRIS ROEHL and KEN STANZEL are with Miller Electric Mfg. Co. (www.millerwelds.com), Appleton, Wis.
has made it much easier to train new welders and for those new welders to achieve quality results quicker. For many employers facing the welder shortage, this capability alone is sufficient to turn to GMAW-P.

This, however, is only one of the benefits of current GMAW-P technology. Others include the following:

- **Decreased waste and rework.** Because GMAW-P allows precise control of the heat put into a weld, it eliminates excess heat that can lead to melt-through or warping on thin materials, especially aluminum, and provides better control for less-than-optimal fitup — Fig. 2.
- **Eliminate spatter and associated costs.** Today’s systems monitor arc conditions thousands of times per second and can detect and clear a short before it becomes a problem or causes spatter — Fig. 3. This eliminates the need to apply and remove antisputter material. Parts can often go to painting without the need for postweld grinding.
- **Allow out-of-position welding.** Unlike spray transfer, which requires welding in the flat or horizontal positions, GMAW-P allows the pool to freeze slightly between current peaks. This means it can be used in out-of-position welding and eliminates the need to reposition weldments, as one would with spray transfer.
- **More productive aluminum welding.** While it used to require a skilled GTA welder to achieve a good bead appearance on aluminum, GMAW-P rivals gas tungsten arc welding in appearance and can replace that process in many applications, increasing travel speeds by 30% and reducing heat by 50% — Fig. 4. Additionally, becoming proficient in GMAW-P requires less training than with GTA. Compared to short-circuit gas metal arc welding, GMAW-P ensures good fusion.
- **Maintain base metal chemistry.** Many applications, such as cladding with Inconel®, require precise control over the heat in order to maintain the chemistry and properties of the alloy — Fig. 5. The precision of GMAW-P provides this level of control. Systems optimized for these applications, both in manufacturing and construction, will contain programs for each alloy, shielding gas, and wire diameter likely to be encountered. This eliminates operator guesswork and helps less skilled welders become productive quicker.
- **Larger wires — less cost.** GMAW-P can also allow the operator to use larger-diameter wires. Larger-diameter wires are usually less expensive per pound than thinner wires. In the case of aluminum, larger wire is easier to feed and less prone to birdnesting.
- **Decreased training time.** Today’s GMAW-P technology enables new operators to start making production-quality welds in less time, and it gives experienced operators even more control over bead appearance. It allows operators to hold a short (¼ to ½-in.) electrode extension for better control over the weld pool. Further, it automatically compensates for contact tip-to-work-distance variations, maintaining a constant electrode extension to ensure a consistent weld.

**Origins of GMAW-P**

Pulsed gas metal arc welding was developed as an alternative to short circuit and spray transfer modes in the shipbuilding industry.

In short circuit transfer, the welding wire shorts against the base metal many times each second to deposit metal into the weld pool. Wire feed speeds, deposition rates, and voltages are typically lower than in other modes. It is also prone to producing spatter. One of its advantages is that, because it produces a smaller, cooler weld pool that solidifies quickly, it can weld in all positions.

In spray transfer mode, the wire does not short against the base metal. Instead, with higher heat input, the arc sprays a stream of molten metal across the arc, achieving higher deposition rates, but also producing a larger weld pool that limits its use to horizontal and flat position welding. With its higher heat, it is prone to melt-through on materials thinner than ¼ in.

In pulsed spray transfer, commonly called GMAW-P, the current switches between a high peak current and a low background current. At the current’s peak, a droplet is pinched off the wire and sprayed toward the weldment. The current then drops to a background level. During this period the pool is allowed to freeze slightly, providing the out-of-position capabilities. Yet the process maintains many benefits of spray transfer, such as good fusion, high deposition rates, and/or fast travel speeds.

**First and Second Generation GMAW-P**

In general, there are several parameters considered when an engineer creates a pulsed waveform, as listed below.

1. **Peak current (heat).** Increasing peak current increases melt-off rate and arc length, and slightly increases average amperage and heat input.
2. **Background current (arc stability).** Increasing background current increases arc length, average amperage, heat input, penetration, and pool fluidity.
3. **Pulse frequency.** Increasing the pulses per second increases arc length, average amperage, and heat input.
4. **Pulse width.** Increasing pulse width increases arc length, heat input, and penetration and cone width.
5. **Pulse rise and falloff time.** Adjusting these can affect the sound and feel of the arc. Some of today’s high-end machines tailor these values for specific applications.

These parameters will vary according to wire size and alloy, metal thickness, po-
position of weldment, type of gas, desired bead profile, and operator preference.

In the preinverter days, however, when GMAW-P was introduced, very few of these parameters could be adjusted. Operators were limited to setting the frequency to 60, 120, and, in some cases, 180 Hz (multiples of input frequency) and peak amperage.

The introduction of inverters gave much more control over the pulse parameters. An inverter takes input power, filters it, and creates an output that is independent of input. They are lighter than conventional power sources, and some continue to provide a stable output regardless of wide fluctuations in input power.

Unfortunately, the ability to set all of the pulse parameters added a layer of complexity to the equipment that usually required a welding engineer to operate. There were no formulas. Typically, a welding engineer would set up the equipment in a lab and develop programs, each based on material, gas, and wire diameter. At 15 “teach points” in the wire feed speed spectrum, the engineer would adjust pulse parameters for optimal results. These results were then stored. If the operator chose a wire feed speed between the teach points (based on material thickness), the inverter would interpolate the nearest teach points to arrive at the parameters.

This was a laborious process, and most manufacturers developed a library of common welding programs. If the user was fortunate, the programs worked as intended; however, field conditions often didn’t match the lab conditions and could necessitate altering the programs. This could mean having a welding engineer or the manufacturer reprogram each of the teach points. Or it could mean flying in a welding engineer to change the programs on site.

In addition, response times were much slower than with today’s technology. Overshoots and undershoots, which refer to the control circuit’s going beyond the targeted peak or background current, were difficult to control and could lead to arc outages. If a short circuit did occur, it could take several cycles to clear it. The responsiveness of the technology has been likened to driving a car and trying to adjust your direction by looking in the rearview mirror and only opening your eyes once every minute.

Unfortunately, this generation of GMAW-P machines turned off many companies to the possibilities GMAW-P offers.

Taking Today’s Pulse

With current technology, response times have vastly improved to thousands of times per second, and the programs are more robust. Although top-line machines give the option to easily write one’s own programs, today’s user is freed from setting pulse parameters and is able to take immediate advantage of the benefits GMAW-P offers.

For example, one popular all-in-one GMA/GMAW-P machine contains pulse programs for mild steel, stainless steel, 4000 and 5000 series aluminum, and metal cored wire in various wire sizes and gas combinations. The user only has to dial in the wire size, type and gas, and adjust wire feed speed based on material thickness. An arc control switch allows the user to set arc preferences, such as length and width.

More advanced equipment contains more programs and is optimized for use in high-volume manufacturing, pipe fabrication, shipbuilding, power plants, and other applications where special alloys are used. It does this without sacrificing ease of operation. For instance, a welder who wants to lay down Inconel® cladding can simply turn to that program, set the desired arc length and wire feed speed, and start welding.

Today’s technology offers adaptive GMAW-P, which will maintain arc length even if the electrode extension changes.
As an example, when welding into a corner, adaptive GMAW-P machines will sense the voltage change and immediately increase or decrease power to maintain the arc length. This gives the user the ability to hold a shorter arc length for more control without fear of shorting the wire. This benefits both the novice welder who may vary electrode extension and the experienced welder who wants more pool control.

**Constant Voltage (CV)**

While some GMAW-P machines adapt to changes in arc length by varying the pulse parameters, the technology found in today’s top-line machines also changes how they regulate voltage and current in the peak and background phases to optimize travel speed and pool control on different materials. The regulation of voltage in both the peak and background phases of the pulse cycle is ideal for increasing travel speed. While the need for speed is universal, materials such as aluminum and stainless steel require a softer arc to remain stable. The softening is added with a slope or curve to the fall edge of the pulse transition.

These systems may be optimized for specific uses, such as fixed automation, flexible automation, and semiautomatic and pipe fabrication, as well as specialized programs for aluminum and stainless welding and high-speed, out-of-position welding ideal for automated systems. New programs can easily be developed and shared, across the plant or across the country, and uploaded with a standard Personal Data Assistant (PDA).

Because of the sophisticated software in today’s units, programs for controlling craters or for providing better arc starts are easily built in. On some of today’s top-line models, a series of programs can be chosen ahead of time to be available at the click of the gun’s trigger (or instruction from the robot controller), allowing an easy switch between preferred settings for various weld configurations.

Another feature found in some top models is the ability to switch between various GMA processes on the fly. Software-driven GMAW-P programs allow the user to use one wire and one gas for several processes and eliminate the need and time to switch between machines for multipass welding procedures.

**Take Your Pulse Again**

If your view of GMAW-P was shaped by experiences with the earlier technology, it’s time to take another look. You no longer have to be a welding engineer to take advantage of the benefits GMAW-P has to offer. It’s not a cure all. Conventional gas metal arc welding will always have a place. But for those who can take advantage of GMAW-P, from small fabrication shops to large manufacturers, double-digit productivity increases are the norm and not the exception.◆
As a child, you may have dreamed about running away to join the circus, but have you ever wondered what makes the circus run? The Greatest Show On Earth® is made possible thanks in part to the dedicated industry professionals at Feld Entertainment, Inc.’s, operational office in Palmetto, Fla. Approximately 200 employees work at the facility; of those, about 15–20 do some welding. The company’s corporate offices are in Vienna, Va.

“We are the world’s largest producer of live family entertainment,” said Scott Dickerson, vice president, Florida operations and show support. “This includes Ringling Bros. and Barnum & Bailey® Circus, Disney on IceSM, and Disney Live! We have 18 shows traveling worldwide.”

The buildings at Feld’s Florida location house different departments that contain everything from materials and machines for fabricating scenery to warehousing for the colorful costumes worn by human and animal performers. Also included are areas to support a transportation department, purchasing, IT, portable ice floor operations, lighting, sound, safety, scenic shop, costume, and rail car operations.

“Our job is to build the shows and to support those on the road,” Dickerson said. And while making ornate sets for shows or revamping the rail cars the circus entertainers travel and live in is no small task, this type of work goes on at the site year after year.

Operating a Production

When a show is to be built, the company hires a director along with a creative team encompassing choreography, music, scenic, costume, lighting, and video, who work together on the vision of what the show becomes. The venues Feld presents its numerous shows in are basically used as a shell. The company supplies everything needed to put on a show, such as sets, portable ice floors, lighting, and sound. Sometimes items are built to fit a particular venue depending on size limitations.

KRISTIN CAMPBELL (kcampbell@aws.org) is associate editor of the Welding Journal.
The Fine Points of Fabrication

Sam Morton, show equipment manufacturing manager, manages the fabrication shop responsible for building items that attach to the trusses, packaging, crating, as well as performance, backstage, and all support equipment.

“When you build equipment people have to hang on and their lives depend on it that’s unique,” Morton said.

Gas metal arc welding (GMAW) is the standard process used at the facility. Gas tungsten arc welding (GTAW) is performed on aluminum.

A breakdown of the metals used in this shop is 80% steel, 19% aluminum, and 1% stainless. Animal enclosures, feeding trays like those to hold meat for the tigers, and items that cannot have any rust are made with stainless steel.

Oxyacetylene and plasma cutting are also utilized. “If we are cutting plate steel, we use plasma. That’s mostly new fabrication. We use the (acetylene) torch for existing stuff,” Morton explained. The thicknesses range from 16 gauge to 1 in.

In addition, the circus travels with a maintenance shop. Shows are equipped with GMA/flux cored arc machines capable of welding steel or aluminum. “That way someone who is on tour can do minor repairs,” Morton said.

Assembling Handy Objects

With new projects to handle practically each week, welder Terrance Evans finds his work exciting. “I just love creating stuff,” Evans said. One of his past creations, was ring curves for the circus using steel tubing and GMAW.

Recently, he was building wardrobe racks on which to hang costumes — Fig. 1. “It’s like a portable closet,” Evans said. Made with carbon steel tubes, each 6-ft-tall rack will have two legs with a round bar across the top for the hangers, braces on its bottom to provide support, and wheels for mobility. A lot of preparation was required for Evans to fabricate the pieces and weld them together. Afterward, they will be painted, get loaded on a truck, and shipped out.

Not that long ago another welder, Dan Robinson, was in the process of putting together the bases for sets of crates — Fig. 2. Made from mild steel, T-bar specifically, these will contain curtains around 30 ft tall and 60–70 ft wide. “It’s a box on wheels,” Robinson said. They will have plywood sides and lids; holes were also punched in the metal to hold the plywood. For these, Robinson did cutting, fitting, and used GMAW.

“You never know what you are going to see coming in the door every day,” Robinson said. He has even made trapeze platforms and enclosures for animal acts.

Making Items Transportable

Just like sets, wardrobe racks, and crates need to be easily moved around, the same is true for other pieces. Even the circus equipment will eventually end up on a truck, so everything built has to break down for fitting either into a shipping container, which still ends up on a truck, or into a semi. Crates are built to fit side by side for fitting in a truck or a container for shipping. The semi tractor-trailer beds are 53 ft long.

“We can’t take it down to the last nut and bolt, but it needs to fit in a truck,” Dickerson said. “We want it strong, but not too heavy, so we can break it down.”

Therefore, a fine balance is required to build articles durable enough to last and be safe, while being able to be taken
apart for shipping. After all, a show may last five or six years. “We have one show that’s been on the road since 1995,” Dickerson said. “We have made creative changes to the show; however, the infrastructure remains essentially the same.”

**Scene Shop Aspects**

Rick Papineau is director of the Hagenbeck Wallace scenic shop. Named for an old circus, this area covers 35,000 sq ft and employs 20 full-time staff; temporary workers are hired as necessary. Ten or eleven employees here can weld.

“We don’t get technical drawings — the designers just give us drawings of what they want it to look like when it’s done,” Papineau said. This provides flexibility in how a task is accomplished.

Matt Freddes, studio production manager, also works in the scenic shop. “We get to play with all kinds of shapes and materials. We’re actively doing something new all the time,” Freddes said.

Figuring out how the components will work is challenging. Freddes added; building them normally takes three months or so. Full production takes more than a year of thought.

When looking for fabricators, skill levels are tested, and on-the-job training takes place. Many new people learn GTAW here.

“When hiring a new employee, most have an architectural/welding background,” Papineau said. Extra teaching occurs as well at in-house sessions each year. “We really like to cross train as much as possible,” he added.

**Creating Stunning Scenery**

Projects range from simple to elaborate. “When we start working on a show, we start with the framework,” Papineau said — Figs. 3, 4. “So the shop will be filled with welding at the beginning, later painting may fill the shop. Everyone here is basically an artist.” Free-form work occurs here, too, and one bending machine was even built in-house.

“Almost all the underframing is made of aluminum. A variety of materials is used for the rest. If it’s a structural element, we use steel,” Papineau explained. Primarily GTAW is used on aluminum, although tacking may take place using GMAW.
In particular, due to its light weight, 6061 aluminum is used for frames. "We also use it because we have to avoid rust. With the ice shows, everything’s wet in a couple of hours," Freddes said.

Various materials are used over the frames with any combination of the following: wood; rubber-coated foam; fiberglass; Lexan, styrene, and vacuum-formed plastics; assorted cloths (muslin, spandex, etc.); screen mesh; plate aluminum; carbon fiber; and vinyl sheet goods.

Earlier this year, a round staircase section of scenery was built in the shop for a new Disney show — Fig. 5. It contains an all-aluminum frame, and the unit breaks into ten pieces. "We use a lot of pins because bolts can get lost. We make it as easy on the show’s crew as possible," Freddes said. "We rarely build a square box in this shop."

Additionally, the scenic sections are not critical assemblies, so there is no formal inspection, but the tubs the elephants stand on are periodically inspected because of the stress the animals’ weight puts on them.

**Town without a Zip Code**

To get from city to city, most of the circus performers, along with the animals, travel by railroad. In fact, the Ringling Bros. and Barnum & Bailey® circus trains are the largest privately owned trains in America. Consisting of the Red and Blue Units, these trains bring the show to many regions of the United States.

"The trains are about 63 cars long and include flat cars and coaches. One train currently has 62 cars and the other 65," said Roy Fullgrapp, vice president of combined operations. All year, they stay on generator power.

On every trip, planned water stops for all the animals are scheduled as well. "We build a room in the elephant cars with video monitors for the handler," Fullgrapp added. This reinforced area is to keep the handler from being crushed by the elephants, especially in the case of a rail accident. However, some animals travel on transport vehicles. Other cast members travel in their own RVs because some acts own the animals and prefer to live where their animals are.

The Gold Unit travels entirely by truck. This strictly overland division goes to smaller cities than the other units.

**Rebuilding Rail Cars**

The company’s rail car department refurbishes the rail cars that make up the circus trains. Workers need 9000 hours to completely recycle one train car. Work starts in January, and the cars are delivered in November or December.

Usually four cars per year are renovated, and this is a combination of cars housing performers and animals. "The train grew by a car this year. We sent four
to them, but only three came back,” Dickerson said. These are remodeled to special specifications depending on who is going to live there.

George Barnhart, manager of exterior rail car production, mentioned 24 people work on the trains overall; the different trades include seven in welding/fabricating.

The circus is phasing out its remaining steel cars and replacing them with aluminum or stainless steel. Shielded metal arc welding, GMAW, and GTAW are used on the rail cars along with plasma arc cutting and carbon arc gouging. The tanks are all GTA welded. The cars exteriors are sandblasted prior to painting.

Shown is a rail car in the beginning stages of gutting and stripping — Fig. 6. This will be a standard car with eight living quarters. Each living unit includes space for a small refrigerator, stove top, TV, sinks, and a bedroom area. Cabinets are outsourced. “It’s much like building a house,” Fullgrapp said. Framing, electrical, safety equipment, and plumbing work will also take place. New holes are cut for windows whenever needed. It might be for a couple and child though other layouts are for individuals. “We make it as homey as we can,” Barnhart said.

Old rail cars are bought from Amtrak salvage and refurbished as opposed to buying new ones. “A brand-new car is about $7 million, and there’s a four-year waiting list,” Fullgrapp said. Another reason for using old cars is that newer ones have a lower profile (meaning they are not as high as the older ones used), because most new cars are built for commuter trains rather than cross-country use.

“When we rebuild them now, everything is 100% flame retardant,” Fullgrapp said. “We also recertify them so they meet Amtrak standards.”

Inspection takes place as well. “We check the structure for cracks with dye penetrant,” Fullgrapp said. Dye penetrant testing is done on some other components, too; this kind of testing is done in-house.

Besides those being refurbished, the company keeps additional rail cars on its lot. “We’re storing the extras for when we get the time to redo them and as backups,” Fullgrapp explained. “Steel cars we’re scrapping out. Aluminum and stainless steel cars we’ll refurbish.” The life expectancy of a circus car is 20 years.

“We build all of the accessories that go underneath,” Barnhart said, such as water tanks and donnikers (septic or black water tanks).

“If we do a repair on the truck portion of the car (the undercarriage part), we send it to Georgia for heat treatment,” Fullgrapp added.

During the summer, these rail cars are covered with large tarps to provide a better environment for workers; after all, it gets quite warm in Florida — Fig. 7. “It also helps keep the grey paint from blowing around the yard and to allow the paint to dry if it rains,” Fullgrapp said.

Springing Ahead

Staff members at Feld’s facility play an important role in making sure these shows become a reality for people to enjoy. And to think, this side is only one part of a whole arena that includes numerous factors like the performers (clowns, acrobats, daredevils, dancers, ice skaters, actors) as well as animals (tigers, elephants, horses) playing their roles.

So the next time you take a child to see one of these productions, you’ll know some of what it takes to make the circus run.
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To explore this rewarding opportunity, call (800) 443-9353, ext. 448 or 211, or email epagoaga@aws.org.
If you and your company are just starting out with friction stir welding (FSW), or if you are interested in learning more about FSW, this is the conference for you. This conference will not be a gathering of academics talking about theory. The aim of this conference is to provide those interested in considering use of FSW with pertinent information on the process so they can evaluate its feasibility for their applications.
FRICITION STIR WELDING CONFERENCE
Wednesday, October 8, 2008 • 8:30 AM – 2:30 PM
Las Vegas Convention Center
Member of AWS, FMA, SME, NAM, or PMA: $345
Nonmembers: $480
Registration Code: W83

Friction Stir Welding History and Licensing
Ian Smith, TWI Ltd.
This presentation will contain a brief review of the history of the early development of FSW and its rapid takeup by industry. It will also discuss the approach TWI uses for the control and exploitation of the intellectual property. Finally, it will briefly review the very large number of patents filed by FSW users.

Friction Stir Welding Tool Designs
Ian Smith, TWI Ltd.
This presentation will describe the evolution of FSW tool designs from the simple forms used to establish the process through to the most popular types used today, and some indications of the future challenges for tools.

Friction Stir Welding and Processing
Murray Mahoney, Consultant
General discussion of FSW including metal flow and defect avoidance, temperature gradient issues, lap vs. butt joints, some tool material and tool design considerations, current applications, FSW limitations, benefits such as properties, and the solid state benefits of welding unweldable alloys and zero emissions, all as they apply to Al, Cu, and Fe based alloys. A description of friction stir processing and its benefits will be included.

Advances in Friction Stir Welding Tool Technology
Scott Packer, Advanced Metal Products
Limitations of FSW have included the feasibility of joining high melting-temperature materials such as steels, stainless steels, and nickel-base alloys. Tool materials able to withstand the high temperatures along with adequate wear resistance during the joining process are required. Generally, there have been two distinct material systems used, including polycrystalline cubic boron nitride (PCBN) and tungsten based materials such as tungsten rhenium alloys. This presentation will cover the development of PCBN materials for FSW, and the development of composite tungsten rhenium alloys with PCBN and diamond reinforcement.

Friction Stir Welding Machines and Configurations
Tim Haynie, Transformation Technologies, Inc.
Friction stir welding is performed on a variety of equipment types ranging from simple milling machine to highly sophisticated purpose-built FSW systems with specialized features and advanced control algorithms. In this presentation, the requirements of the FSW process and the implications on the equipment selection will be discussed. The basics of force control and position control modes are presented and the advantages of each control mode will be discussed. Commercially available machine configurations from several manufacturers will be presented. These include simple two-axis seam welders through multi-axis complex contouring machines with advanced pin-control features.

Eddy Current Array and Ultrasonic Phased-Array Technologies for FSW Inspection
Michael Moles, Olympus NDT
Ultrasonic phased-array technology has demonstrated over the years its capabilities to reliably inspect aluminum friction stir welds, as many aerospace manufacturers have used it during their manufacturing process. Recent developments in eddy current array technology added new perspectives to the FSW evaluation. It is now possible to characterize the tool penetration and minimize the presence of an oxide layer, so-called kissing bond.

Cost/Benefit Analysis for Friction Stir Welding
Jeff DeFalco, ESAB
A cost/benefit comparison is made between conventional fusion-type welding processes to FSW by evaluating their relative production output, production costs, and weldability attributes in various heavy industry applications. Applications will include joining both low and high melting point alloys while assigning numbers to each evaluation.

Robotic Friction Stir Welding, Friction Stir Processing and Supporting Operations
John Hinrichs & Christopher Smith, Friction Stir Link
FSW and FSP are relatively new processes. Principles of the friction stir welding process and FSW and FSP with robots will be discussed. Several FSW robotic applications and an FSP robotic application will be discussed. In addition, robotics used to support manufacturing of FSW products will be described.

Friction Stir Welding Standards and Specifications Used in Today’s U.S. Manufacturing and Fabrication
R. Jeffrey Ding, NASA Marshall Space Flight Center
Discussions will include the AWS FSW Specification for Aerospace Applications. The presentation will also cover standards used in private industry.

Q&A / Panel Discussion
To register or to receive a descriptive brochure, call (800) 443-9353 ext. 455 (outside North America, call 305-443-9353), or visit www.aws.org/conferences
CALL FOR PAPERS

Abstract Deadline: July 15, 2008       Manuscripts Due: October 15, 2008

The American Welding Society® and ASM International® are again organizing the world-recognized International Brazing & Soldering Conference (IBSC). This four-day event will begin with Short Courses offered on Sunday, followed by a three-day Technical Program Monday-Wednesday. IBSC brings together scientists, engineers and technical personnel from around the globe involved in the research, development, and application of brazing and soldering. Parallel sessions allow us to present the latest advances in these joining technologies and will be organized to permit interaction between the two disciplines.

IBSC 2009 Program Organizers invite to submit your work for consideration of inclusion in the technical program. They are accepting 150-200-word abstracts describing original, previously unpublished work. The work may pertain to current research, actual or potential applications, or new developments. Whereas commercialism must be avoided to maintain the high level of technical quality and integrity of the IBSC conferences, the new brazing applications and case histories are most welcome.

The technical program will include a special ½ day session focused on practical and innovative applications of brazing and soldering. The Tabletop Exhibit will provide a forum for commercial presentations and demonstrations of state-of-the-art brazing and soldering materials, processes and equipment. Check our website for details. The Poster Session will allow yet another opportunity to present the interesting developments in brazing and soldering technologies.

A Conference Proceedings containing only full manuscripts of the accepted research papers will be published to capture these high-quality technical presentations for later reference. Presentations focused on practical applications of brazing and soldering will also be included in the conference proceedings.

Below are some of the topical areas covered at IBSC

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To submit your work for consideration, visit our website at www.aws.org/education/ibsc and follow the instructions at “CLICK HERE TO SUBMIT YOUR ABSTRACT”. All abstracts submissions must be completed by close-of-business on Tuesday, July 15, 2008. Before submitting your abstract, we ask that you carefully consider your ability to present your work at the conference. Speakers are required to pay a (reduced) conference registration fee, and are totally responsible for their travel, housing and any related expenses.

This premiere event is truly one that anyone involved in the brazing and soldering community should plan to attend.

Mark your calendar now, and if you are interested in presenting your work at the conference, submit your abstract no later than July 15, 2008.
This conference has been developed specifically for welding/materials joining educators. The conference presentations will focus on those topics that directly affect educators, the futures of their respective programs, and their students.

Monday, October 6, 2008 • 8:50 AM – 4:15 PM
Conference fee: $149
Registration Code: W80

To register or to receive a descriptive brochure, call (800) 443-9353 ext. 455 (outside North America, call 305-443-9353), or visit www.aws.org/conferences
Innovations in the aircraft and aerospace industries will take center stage at this conference. These industries are taking giant steps in cost reduction. One is the use of composites in place of aluminum in aircraft and space vehicles. Another is to find ways to build critical parts from the ground up, rather than ordering expensive forgings and castings that have to be machined down to size, at great expense.

Welding is in the very thick of it on both fronts. Improved processes are being developed to weld many of the carbon composite structures. In the world of “born to shape parts,” such processes as electron beam and laser beam welding are being called on to get the jobs done quickly, efficiently, and at reasonable cost. Emphasis will be given to friction stir welding, fiber laser welding, and the gas-shielded welding processes. The role of titanium is growing, while the emergence of a number of new aluminum-lithium alloys pose challenges to welding technologies. Ultrasonic welding, a front-runner for the welding of thermoplastic composites, will also be on the agenda.

The vehicles planned to carry man to the moon by 2010 and later even to Mars — part of the Orion project — will also be discussed.

**Welding of Engineering Plastics and Composites Conference**
*Orlando, Florida  
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Welding has found a new home in the fabrication of engineering plastics. The welding of engineering plastics is already a way of life in the automotive industry, and this technology is spilling over into many areas, including equipment used in medicine. Engineering plastics, as opposed to commodity plastics, include such thermoplastic grades as nylon, polycarbonates, polypropylene, ABS, PVC, acetals, acrylics, vinyls, and others. The established welding processes for plastics include ultrasonic welding, hot plate welding, vibration welding, spin welding, and hot gas welding. Laser welding is also starting to attract considerable attention.

Among the speakers at the Orlando conference will be experts from several of the plastics-producing companies and engineers who are knowledgeable about the processes used to weld these materials.

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Here's What's Happening at the Show

The following conferences will be held during the FABTECH International & AWS Welding show on the dates listed. For more information, contact American Welding Society (800/305) 443-9353, ext. 455, or visit www.aws.org/conferences.

- **New Technologies in Thermal Cutting**, Oct. 6
- **New Nondestructive Testing Technologies**, Oct. 7
- **Friction Stir Welding**, Oct. 8

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COMING EVENTS

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


SES 2008 Annual Conf. — The World of Standards — Is It Really a Zoo Out There? Aug. 18, 19, Marriott San Diego Mission Valley, San Diego, Calif. Contact H. Glenn Ziegenfuss, hgzigg@worldnet.att.net; or visit www.ses-standards.org.

Coatings for Africa 2008. Aug. 19–21, Champagne Resort, Central Drakensberg, Kwazulu-Natal, South Africa. E-mail rosalie@coa.co.za; visit www.coatingsforafrica.org.za.


♦ FABTECH International & AWS Welding Show. Oct. 6–8, Las Vegas Convention Center, Las Vegas, Nev. This show is the largest event in North America dedicated to showcasing the full spectrum of metal forming, fabricating, tube and pipe, welding equipment, and technology. Contact American Welding Society, (800/305) 443-9353, ext. 455; www.aws.org.


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Jul 9-13

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Aug 25-29 · Nov 17-21

Welding for the Non Welder
Aug 11-14 · Nov 3-6

Arc Welding Inspection & Quality Control
Aug 4-8 · Oct 13-17

Weldability of Metals, Ferrous & Nonferrous
Jun 30-Jul 3 · Jul 28-Aug 1 · Aug 25-29 · Sep 22-26

Liquid Penetrant & Magnetic Particle Inspection
Aug 18-22 · Nov 10-14

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JULY 2008


JOM-15, 15th Int’l Conf. on the Joining of Materials, and 6th Int’l Conf. on Education in Welding. May 3–6, 2009, Helsingør, Denmark. Contact JOM Institute, jom_aws@post10.tele.dk.

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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.


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Fundamentals of Brazing Seminars. A 2½-day course beginning Sept. 9, Toronto, Ont., Canada; Oct. 21, Milwaukee, Wis. Topics include technology overview, fundamental steps of brazing, braze design, filler metals, heating methods, and problem solving. Call (414) 769-6000, ext. 505; visit www.lasercmillhaupt.com.


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


Laser Safety Training Courses. Courses based on ANSI Z136.1, Safe Use of Lasers, presented in Orlando, Fla., or at customer’s locations. Contact Laser Institute of America, (800) 345-3737.


Welding Introduction for Robot Operators and Programmers. This one-week course is presented in Troy, Ohio, or at customers’ locations. Contact Hobart Institute of Welding Technology, (800) 332-9448, ext. 5603; www.welding.org.

Welding Skills Training Courses. Courses include weldability of ferrous and nonferrous metals, arc welding inspection and quality control, preparation for recertification of CWIs, and others. Contact: Hobart Institute of Welding Technology, (800) 332-9448, visit www.welding.org.

An Important Event on Its Way?

Send information on upcoming events to the Welding Journal Dept., 550 NW LeJeune Rd., Miami, FL 33126. Items can also be sent via FAX to (305) 443-7404 or by e-mail to woodward@aws.org.
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)

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SEMINAR DATES</th>
<th>EXAM DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY</td>
<td>Jul. 19</td>
</tr>
<tr>
<td>Beaumont, TX</td>
<td>Jul. 20-25</td>
<td>Jul. 26</td>
</tr>
<tr>
<td>Milwaukee, WI</td>
<td>Jul. 20-25</td>
<td>Jul. 26</td>
</tr>
<tr>
<td>Cleveland, OH</td>
<td>Jul 27-Aug. 1</td>
<td>Aug. 2</td>
</tr>
<tr>
<td>Denver, CO</td>
<td>Jul 27-Aug. 1</td>
<td>Aug. 2</td>
</tr>
<tr>
<td>Philadelphia, PA</td>
<td>Jul 27-Aug. 1</td>
<td>Aug. 2</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>Aug. 3-8</td>
<td>Aug. 9</td>
</tr>
<tr>
<td>San Diego, CA</td>
<td>Aug. 3-8</td>
<td>Aug. 9</td>
</tr>
<tr>
<td>Charlotte, NC</td>
<td>Aug. 10-15</td>
<td>Aug. 16</td>
</tr>
<tr>
<td>San Antonio, TX</td>
<td>Aug. 10-15</td>
<td>Aug. 16</td>
</tr>
<tr>
<td>Rochester, NY</td>
<td>EXAM ONLY</td>
<td>Aug. 16</td>
</tr>
<tr>
<td>Bakersfield, CA</td>
<td>Aug. 17-22</td>
<td>Aug. 23</td>
</tr>
<tr>
<td>Portland, ME</td>
<td>Aug. 17-22</td>
<td>Aug. 23</td>
</tr>
<tr>
<td>Salt Lake City, UT</td>
<td>Aug. 17-22</td>
<td>Aug. 23</td>
</tr>
<tr>
<td>Houston, TX</td>
<td>Sept. 7-12</td>
<td>Sept. 13</td>
</tr>
<tr>
<td>Pittsburgh, PA</td>
<td>Sept. 7-12</td>
<td>Sept. 13</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>Sept. 7-12</td>
<td>Sept. 13</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>EXAM ONLY</td>
<td>Sept. 18</td>
</tr>
<tr>
<td>Las Vegas, NV</td>
<td>Sept. 14-19</td>
<td>Sept. 20</td>
</tr>
<tr>
<td>Minneapolis, MN</td>
<td>Sept. 14-19</td>
<td>Sept. 20</td>
</tr>
<tr>
<td>St. Louis, MO</td>
<td>Sept. 14-19</td>
<td>Sept. 20</td>
</tr>
<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY</td>
<td>Sept. 20</td>
</tr>
<tr>
<td>Anchorage, AK</td>
<td>EXAM ONLY</td>
<td>Sept. 20</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>Oct. 19-24</td>
<td>Oct. 25</td>
</tr>
<tr>
<td>Tulsa, OK</td>
<td>Oct. 19-24</td>
<td>Oct. 25</td>
</tr>
<tr>
<td>Long Beach, CA</td>
<td>Oct. 26-31</td>
<td>Nov. 1</td>
</tr>
<tr>
<td>Newark, NJ</td>
<td>Oct. 26-31</td>
<td>Nov. 1</td>
</tr>
<tr>
<td>Portland, OR</td>
<td>Oct. 26-31</td>
<td>Nov. 1</td>
</tr>
<tr>
<td>Cleveland, OH</td>
<td>Nov. 2-7</td>
<td>Nov. 8</td>
</tr>
<tr>
<td>Atlanta, GA</td>
<td>Nov. 16-21</td>
<td>Nov. 22</td>
</tr>
<tr>
<td>Dallas, TX</td>
<td>Nov. 16-21</td>
<td>Nov. 22</td>
</tr>
<tr>
<td>Roanoke, VA</td>
<td>Nov. 16-21</td>
<td>Nov. 22</td>
</tr>
<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY</td>
<td>Nov. 22</td>
</tr>
<tr>
<td>Sacramento, CA</td>
<td>Nov. 30-Dec. 5</td>
<td>Dec. 6</td>
</tr>
<tr>
<td>Spokane, WA</td>
<td>Nov. 30-Dec. 5</td>
<td>Dec. 6</td>
</tr>
<tr>
<td>Syracuse, NY</td>
<td>Nov. 30-Dec. 5</td>
<td>Dec. 6</td>
</tr>
<tr>
<td>St. Louis, MO</td>
<td>EXAM ONLY</td>
<td>Dec. 6</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>Dec. 7-12</td>
<td>Dec. 13</td>
</tr>
<tr>
<td>Reno, NV</td>
<td>Dec. 7-12</td>
<td>Dec. 13</td>
</tr>
</tbody>
</table>

9-Year Recertification Seminar for CWI/SCWI

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SEMINAR DATES</th>
<th>EXAM DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orlando, FL</td>
<td>Sept. 8-13</td>
<td>NO EXAM</td>
</tr>
<tr>
<td>Dallas, TX</td>
<td>Oct. 20-25</td>
<td>NO EXAM</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>Dec. 1-6</td>
<td>NO EXAM</td>
</tr>
</tbody>
</table>

For current CWIs and SCWIs 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)

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SEMINAR DATES</th>
<th>EXAM DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philadelphia, PA</td>
<td>Aug. 18-22</td>
<td>Aug. 23</td>
</tr>
<tr>
<td>Atlanta, GA</td>
<td>Sept. 15-19</td>
<td>Sept. 20</td>
</tr>
<tr>
<td>Tulsa, OK</td>
<td>Oct. 20-24</td>
<td>Oct. 25</td>
</tr>
<tr>
<td>Atlanta, GA</td>
<td>Nov. 17-21</td>
<td>Nov. 22</td>
</tr>
<tr>
<td>Long Beach, CA</td>
<td>Dec. 8-12</td>
<td>Dec. 13</td>
</tr>
</tbody>
</table>

CWS exams are also given at all CWI exam sites.

Certified Radiographic Interpreter (CRI)

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SEMINAR DATES</th>
<th>EXAM DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Louis, MO</td>
<td>Aug. 18-22</td>
<td>Aug. 23</td>
</tr>
<tr>
<td>Denver, CO</td>
<td>Sept. 15-19</td>
<td>Sept. 20</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>Nov. 17-21</td>
<td>Nov. 22</td>
</tr>
<tr>
<td>Jacksonville, FL</td>
<td>Dec. 8-12</td>
<td>Dec. 13</td>
</tr>
</tbody>
</table>

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.

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 CWI Courses and Exams

AWS training and certification for CWI and other programs are offered in many countries. For international certification program schedules and contact information, please visit http://www.aws.org/certification/inter_contact.html

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. 455 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.

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Several types of discontinuities can result from improper procedures or practices during flux cored arc welding (FCAW). Although many of the discontinuities are innocuous, they adversely affect the weld appearance, and therefore adversely affect the reputation of FCAW. These problems and discontinuities, along with their causes and remedies, are shown in the table below.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible Cause</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>Low gas flow</td>
<td>Increase gas flowmeter setting.</td>
</tr>
<tr>
<td></td>
<td>High gas flow</td>
<td>Clean spatter-clogged nozzle.</td>
</tr>
<tr>
<td></td>
<td>Excessive wind drafts</td>
<td>Decrease to eliminate turbulence.</td>
</tr>
<tr>
<td></td>
<td>Contaminated gas</td>
<td>Shield weld zone from draft or wind.</td>
</tr>
<tr>
<td></td>
<td>Contaminated base metal</td>
<td>Check gas source.</td>
</tr>
<tr>
<td></td>
<td>Contaminated welding wire</td>
<td>Check for leak in hoses and fittings.</td>
</tr>
<tr>
<td></td>
<td>Insufficient flux in core</td>
<td>Clean weld joint faces.</td>
</tr>
<tr>
<td></td>
<td>Excessive voltage</td>
<td>Remove drawing compound on wire.</td>
</tr>
<tr>
<td></td>
<td>Excess electrode stickout</td>
<td>Clean oil from rollers.</td>
</tr>
<tr>
<td></td>
<td>Insufficient electrode stickout (self-shielded</td>
<td>Avoid shop dirt.</td>
</tr>
<tr>
<td></td>
<td>electrodes)</td>
<td>Rebake welding wire.</td>
</tr>
<tr>
<td></td>
<td>Excessive travel speed</td>
<td>Change electrode.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reset voltage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reset stickout and balance current.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjust speed.</td>
</tr>
<tr>
<td>Incomplete fusion or penetration</td>
<td>Improper manipulation</td>
<td>Direct electrode to the joint root.</td>
</tr>
<tr>
<td></td>
<td>Improper parameters</td>
<td>Increase current.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce travel speed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decrease stickout.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce wire size.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase travel speed (self-shielded electrodes).</td>
</tr>
<tr>
<td></td>
<td>Improper joint design</td>
<td>Increase root opening.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce root face.</td>
</tr>
<tr>
<td>Cracking</td>
<td>Excessive joint restraint</td>
<td>Reduce restraint.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preheat.</td>
</tr>
<tr>
<td></td>
<td>Improper electrode</td>
<td>Use more ductile weld metal.</td>
</tr>
<tr>
<td></td>
<td>Insufficient deoxidizers or inconsistent flux-fill</td>
<td>Check formulation and content of flux.</td>
</tr>
<tr>
<td></td>
<td>in core</td>
<td>Check formulation and content of flux.</td>
</tr>
<tr>
<td>Electrode feeding</td>
<td>Excessive contact tip wear</td>
<td>Reduce drive roll pressure.</td>
</tr>
<tr>
<td></td>
<td>Melted or stuck contact tip</td>
<td>Reduce voltage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adjust backburn control.</td>
</tr>
<tr>
<td></td>
<td>Dirty wire conduit in cable</td>
<td>Replace worn liner.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change conduit liner. Clean out with compressed air.</td>
</tr>
</tbody>
</table>

AWS Nominates National and District Officers for 2009

The 2006–2007 Nominating Committee has announced its slate of candidates who will stand for election to AWS national offices for the 2009 term, which begins January 1, 2009.

Nominated are the following candidates:

Victor Y. Matthews, for president; John C. Bruskotter, John L. Mendoza, and William A. Rice Jr. for vice presidents; and Donald B. DeCorte and Thomas A. Siewert for directors-at-large. (Three vice presidents and two directors-at-large are to be elected.)


The Nominating Committees for Districts 3, 6, 9, 12, 15, 18, and 21 have selected the following candidates for election/re-election as District directors for the three-year term Jan. 1, 2009, through Dec. 31, 2011. The nominees are Michael R. Wissesser, District 3; Kenneth A. Phy, District 6; George D. Fairbanks Jr., District 9; Sean P. Moran, District 12; Mace Harris, District 15; John R. Bray, District 18; and Nanette Samanich, District 21.

Victor Y. Matthews

Victor Y. Matthews, an AWS Distinguished Member, is currently completing his third term as an AWS vice president. A member of the Cleveland Section for 39 years, he began his career at The Lincoln Electric Co. in 1963 as a bend brake operator. He attended Lincoln’s welding school and earned all of the diplomas it had to offer. He progressed to work in the Electrode Research and Development group for 13 years. Matthews moved to the manufacturing facility as plant welding engineer where he worked for 12 years. He automated many workstations and put into production the company’s first-ever welding robot for piecework. In 1990, he joined the Service Department with responsibility for engine-driven welding machines. In 1992, he was assigned responsibility for Cleveland-manufactured consumable products worldwide. Currently, he is responsible for consumables, GTA and SMA welding machines, plasma arc cutting machines, inverters under 300 A, and is liaison to the Italian subsidiaries. Lincoln recognized him with its Man of the Year Award in 1995.

He is the past president of the Lincoln Electric Employee’s Association and Sick Benefit Fund. Matthews also is a past chairman of the Cleveland Section. He served as national chairman of the Liaison Committee for the 1995 Welding Show held at the Cleveland IX-Center. Currently, he serves on the Silent Auction Committee, Standards Council, Districts Council, and the Membership Committee. He served eight years on PEMCO, the Executive...
Committee, the Professional Development Council, TFPS, and Government Affairs Liaison Committee.

**Nominated for Vice President John C. Bruskotter**

John C. Bruskotter is currently completing his second term as an AWS vice president. He operates Bruskotter Consulting Services, working for an independent oil and gas operator. Previously, he worked for several years as a project manager with Dynamic Industries, Inc. From 1986 to 2000, he was employed with Houma Industries, Inc., where his positions included fabrication and quality control manager, vice president of operations onshore, offshore fabrication and coatings, and warehousing and maintenance. Bruskotter joined the AWS New Orleans Section in 1993, where he served as its treasurer and vice chair. From 1999 to 2000, he served as both the Section chairman and District 9 deputy director.

**Nominated for Vice President John L. Mendoza**

John L. Mendoza is currently completing his first term as an AWS vice president. He is a journeyman welder, AWS Certified Welding Inspector, and Certified Welding Educator, who has performed power plant maintenance for CPS Energy, San Antonio, Tex., for 32 years. In 1994, he was promoted to Technical Trainer, responsible for developing training programs and training power plant welders. In 1996, he earned his Craft Instructor certification from the National Center for Construction Education and Research and was hired as an adjunct welding instructor for Texas A&M University. In 2005, Mendoza was elected to the Board of Directors of SkillsUSA College/Postsecondary Division. For the past two years, he has chaired the Texas SkillsUSA welding competition. He is a 32-year member of the International Brotherhood of Electrical Workers, Local 500, and a past chair of the St. Philip’s College welding advisory committee. He has received the District Dalton E. Hamilton Memorial CWI of the Year Award.

**Nominated for Director-at-Large Donald B. DeCorte**

Donald B. DeCorte is vice president, sales and marketing, a member of the board of directors, and a co-owner of RoMan Mfg. Inc. in Grand Rapids, Mich., where he has worked for 14 years. A member of the AWS Detroit Section since 1980, he has chaired most committees, served as Section chairman (2003–2004), and has been active nationally and internationally on Society business. He served on four Detroit Sheet Metal Welding Conference committees and chaired the vendor display committee. DeCorte has been in the welding industry for 29 years, working primarily in the resistance welding field. He studied marketing, management, and business communications at Malcom College in Warren, Mich., and Davenport University in Grand Rapids.

**Nominated for Director-at-Large Thomas A. Siewert**

Thomas A. Siewert is the leader of the Structural Materials Group at the National Institute of Standards and Technology in Boulder, Colo. During the past 25 years, his group has worked on projects such as investigations into the failures of pipelines and buildings (including the World Trade Center towers), as well as welding and consumable issues. Earlier, he was manager of R & D at Alloy Rods in Hanover, Pa. He has been a member of AWS since 1969, served as a Section chairman, and has participated on both national and local committees for more than 30 years. Siewert is a frequent presenter at the ASME Pressure Vessel Code, Section XI. He earned his Ph.D. in metallurgical engineering from the University of Wisconsin-Madison. He was elected an AWS Fellow in 1994. He has received the McKay-Helm Award, R. D. Thomas Jr. International Lecture Award, R. D. Thomas Memorial Award, Best ofthe Program Award from The Lincoln Electric Foundation, and the George E. Willis Award.

**Nominated for District 3 Director Michael Wiswesser**

Michael Wiswesser has been elected to his first term as District 3 director. After receiving his bachelor’s degree in business administration from Kutztown University, he joined the Welder Training and Testing Institute (WTTI) in Allentown, Pa., as operations manager. He has directed the expansion of a number of educational programs, including welding and nondestructive testing. He serves as vice president on WTTI’s board of directors, and serves as treasurer on the Pennsylvania Association of Welding Educators board of directors.

**Nominated for District 6 Director Kenneth A. Phy**

Kenneth A. Phy has been elected to his first term as District 6 director. Phy has worked in the nuclear power industry since 1986. Currently, he is senior project manager at Entergy Nuclear Operations, Inc., James A. FitzPatrick Nuclear Power Plant in Lycoming, N.Y. Earlier he worked for J. P. Bell & Sons, Rochester, N.Y., as a mechanical field engineer, and as a project piping engineer at Catalytic, Inc., in Philadelphia, Pa. He has been an AWS Certified Welding Inspector, and has performed welding engineering and inspection work to the ASME Boiler and Pressure Vessel Code, Section XI. He earned his degree in mechanical engineering from Spring Garden College in Philadelphia, Pa.

**Nominated for District 9 Director George D. Fairbanks Jr.**

George D. Fairbanks Jr. has been elected to his first term as District 9 director after fulfilling the last two years of
Nominations Sought for National Offices

AWS members who wish to nominate candidates for President, Vice President, Treasurer, and Director-at-Large on the AWS Board of Directors for the term starting January 1, 2011, may either:

1. Send their nominations electronically by September 2, 2008, to Gricelda Manalich at gricelda@aws.org, c/o Gerald D. Utrach, Chairman, National Nominating Committee; or
2. Present their nominations in-person at the open session of the National Nominating Committee meeting scheduled for 2:00 to 3:00 P.M., Tuesday, October 7, 2008, at Las Vegas Convention and Visitors Authority, Las Vegas, Nev., during the 2008 FABTECH International & AWS Welding Show.

Nominations must be accompanied by biographical material on each candidate, including a written statement by the candidate as to his or her willingness and ability to serve if nominated and elected, letters of support, plus a 5 × 7-inch head-and-shoulders color photograph.

Note: Persons who present their nominations at the Show must provide 20 copies of the biographical materials and written statement.
The AWS Foundation solicits donations of national company gift cards to auction during its 2008 Silent Auction. All funds raised will go toward scholarships. The gift cards will be available for bid during the FABTECH International & AWS Welding Show to be held Oct. 6–8, 2008, at Las Vegas Convention Center, Las Vegas, Nev. Solicited are gift cards in denominations of $200 to $250 from a variety of companies including Macy’s, Home Depot, Tony Roma’s, Bass Pro Shops, JC Penney, Omaha Steaks, etc. The cards may be purchased by you and donated, or you may send a check and the Foundation will purchase gift cards in your name. With the holidays coming right after the Show, we have found that gift cards offer a great way for Show attendees to do their gift-shopping early.

To donate a gift card, call Nazhdia Prado-Pulido at (800) 443-9353, ext. 250, or e-mail nprado-pulido@aws.org. Special thanks go to the first donors to the 2008 Silent Auction:

AWS Rochester Section
Nancy and Barry Carlson
Ray and Sandy Shook
Howard M. Woodward
Indiana Section’s Mid-West Welding Tournament Marks Its 30th Successful Year

Welding students from Indiana, Kentucky, and Illinois competed April 8–10 for top honors at the 30th Annual Mid-West Team Welding Tournament hosted by the AWS Indiana Section. The 110 students in 22 teams competed for more than $10,000 in trophies and prizes. Making it all happen were Gary Tucker, John Myers, Ric Eckstein, Tony Brosio, Bennie Flynn, Chair Gary Dugger, Dave Jackson, Mike Anderson, Bob Richwine, Dick Alley, District 14 Director Tully Parker, Dennis Klingman from Lincoln Electric, and Dennis Marks, representing AWS headquarters.

Concurrently, a Weld Job Fair, open to the public, offered representatives from 15 companies the opportunity to discuss their job openings and demonstrate their latest welding products. Dave Jackson cooked the hundreds of hot dogs and burgers served free to the crowd.

The tournament, held at New Castle Area Vocational School in New Castle, Ind., concluded with an awards-presentation program and dinner. Dennis Marks, AWS managing director, education services, was the featured speaker. Welding instructor Mike Anderson presented the special awards including the Dan Rayshick Award to Ed Wyatt, Clifford Hunt Awards to Praxair and Bob Richwine, Ivan Simmons Award to Harvey Parker, and the AWS Professionalism and Sportsmanship Award to Phil Bedel.

As in the past tournaments, each five-student team completed projects using shielded metal arc, gas metal arc, gas tungsten arc, and flux cored arc welding, and one team member who took a 300-question written exam on welding theory. Already, plans are underway to make the 31st Annual Mid-West Welding Tournament a bigger and better event.

Some of the Indiana Section members who made the 30th Annual Mid-West Team Welding Tournament a success are (standing, from left) John Myers, Dave Jackson, Vice Chair Tony Brosio, Chairman Gary Dugger, and Ric Eckstein; and (front, from left) Secretary Bob Richwine, Bennie Flynn, and Gary Tucker. See additional photos on page 78.

Districts Council Approves Section Charters

On May 18, 2008, after due consideration, Districts Council approved:

- The charter of the AWS Chile International Section.
- The Council in other actions also:
  - Approved the Student Chapter charter for the AWS Des Moines High School Central Campus Student Chapter, District 16
  - Approved the Student Chapter charter for the Los Angeles Trade-Technical College Student Chapter, District 21, and
  - Approved the AWS ESPE-Ecuador Student Chapter, Quito, Ecuador.

The Council approved the reinstatement of the Student Chapter charter for AWS Texas A&M Student Chapter, District 18.

AWS Attends Japan Welding Show

Jeff Weber (far right), AWS associate executive director, along with a line of dignitaries, prepares to cut the ribbon in the opening ceremony for the Japan International Welding Show 2008. Organized by the Japan Welding Engineering Society and Sanpo Publications, Inc., the show attracted 202 exhibitors to five exhibition halls in the Intex Osaka exhibition complex. Weber represented the American Welding Society in the ceremony, as well as in meetings with the representatives of the show organizers. He, along with Welding Journal Publisher Andrew Callison, staffed the AWS exhibition at the show.
WS 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. Draft copies of AWS national standards may be obtained from Rosalinda O’Neill, (800/305) 443-9353, ext. 451, roneill@aws.org. The review expiration date is shown.

**Standards for Public Review**


**ISO Standards for Public Review**

Copies of the following draft International Standards are available for review and comment through your national standards body, which in the United States is ANSI, 25 W. 43rd St., 4th Fl., 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; (305) 443-9353, ext. 466. Otherwise contact your national standards body.

ISO/DIS 9606-1.2 — Qualification testing of welders — Fusion welding — Part 1: Steels

ISO/DIS 17672 — Brazing — Filler metals

**New Standards Projects**

C1.5:200X, Specification for the Qualification of Resistance Welding Technicians. This specification establishes the requirements for qualification of Resistance Welding Technicians (RWT) employed in the welding industry. The minimum experience, examination, application, qualification, and requalification requirements and methods are defined herein. This specification offers a method for technicians to establish a record of their qualification and abilities in welding industry work such as development of machine troubleshooting, processes controls, quality standards, problem solving, etc.

Stakeholders: Manufacturing organizations involved with resistance welding, such as automotive, aerospace, resistance welding equipment manufacturers, and suppliers to these industries. Revised standard. Call A. Alonso, ext. 299.


Stakeholders: Companies seeking guidance on the avoidance of cold cracking using the following main input parameters: steel composition, welding heat input, joint geometry and material thickness, weld hydrogen level, and preheat. Revised standard. Call M. Rubin, ext. 215.

**Technical Committee Meetings**

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


Aug. (TBA), D3 Committee on Welding in Marine Construction. Ketchikan, Alaska. Call B. McGrath, ext. 311.
International Certification Agents Meet in Miami

The International Agency Symposium was held at AWS headquarters in Miami, Fla., April 28–30 for 42 attendees representing welder certification agencies in India, Dubai, Nigeria, Egypt, Russia, Saudi Arabia, Taiwan, China, Korea, Japan, Singapore, Hong Kong, Portugal, Mexico, Spain, Trinidad, Brazil, Venezuela, Ecuador, Colombia, France, Malaysia, Chile, and Brunei. AWS Executive Director Ray Shook opened the program with an introduction of Bob Wing of World Engineering Xchange Ltd. (WEX). In February, WEX was engaged as the Society’s agency responsible for auditing AWS certification seminars and exams outside the United States, and assisting AWS’s international certification agencies with the development of strategies that improve and promote AWS interests within the international market. Presently, AWS has 16 international certification agents operating certification programs in 20 countries. The symposium successfully brought WEX together with the international agencies for a unique networking experience.

Nominees Solicited for Prof. Masubuchi Award

November 3 is the deadline for submitting nominations for the 2009 Prof. Koichi Masubuchi Award. The award is presented each year to one person, 40 years old or younger, who has made significant contributions to the advancement of materials joining through research and development. The award, presented during the FABTECH International & AWS Welding Show, includes a $5000 honorarium. Send a résumé listing background, experience, publications, honors, awards, plus at least three letters of recommendation from researchers to Prof. John DuPont, jnd@lehigh.edu. The award is sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology.

Nominees Sought for Robotic Arc Welding Awards

December 31 is the deadline for submitting nominations for the 2009 Robotic and Automatic Arc Welding Award. The award consists of a $1500 honorarium and a plaque. Funded by private contributions, the award is presented during the FABTECH International & AWS Welding Show. It recognizes individuals for their achievements in the area of robotic arc welding, including the introduction of new technologies, establishment of the proper infrastructure (training, service, etc.) to enable success, and any other activity that significantly improved the state of a company and/or industry.

The nomination packet should include a summary of the candidate’s accomplishments, professional experience, publications, and awards. Send your nomination package to Wendy Sue Reeve, 550 NW LeJeune Rd., Miami, FL 33126. Contact Reeve at wreve@aws.org, or call (800/305) 443-9353, ext. 293.

The award was established in 2004 by the AWS D16 Robotic and Automatic Arc Welding Committee, with the approval of the AWS board of directors.
New AWS Supporters

Supporting Companies
Arkansas Industrial Fabricators, Inc.
1455 Hwy. 270 E.
Sheridan, AR 72150

Centric Alloys Corp.
350 S. Main St., Ste. 215A
Doylestown, PA 18901

Dean Steel
5366 N. Valley Pike
Harrisonburg, VA 22802

Reynolds Mfg. Co., Inc.
621 Railroad Ave.
Avonmore, PA 15618

Southern Metal Fabricators, Inc.
1215 Frazier Rd.
Albertville, AR 35950

Affiliate Companies
Advanced Maintenance Welding
Via Del Palazzo 437
Seravezza, LU 55047, Italy

Aidam Architectural Iron Works
PO Box 1385
Corrales, NM 87048

Boise Ironworks
6475 W. Contractors St.
Boise, ID 83709

Custom Design Iron Works, Inc.
9182 Kelvin Ave.
Chatsworth, CA 91311

Davis Fabricators, Inc.
15765 W. State Rte. 2
Oak Harbor, OH 43449

Eagle Steel Products, Inc.
5150 Loop Rd.
Jeffersonville, IN 47130

Enviro Noise Control Corp. USA
1635 Fostrail Dr.
Loveland, CO 80538

Harden’s Welding Service
13702 Gillman Park
Houston, TX 77073

Military Products Group
37190 Sugar Ridge Rd.
North Ridgeville, OH 44039

Proventus Structural Services, LLC
1428 Pine Wild Dr.
Columbus, OH 43223

Ranch Land Service
3135 Arena Rd.
Colorado Springs, CO 80921

Educational Institutions
Barbara Jordan High School for Careers
5800 Eastex Freeway
Houston, TX 77026

Black Hawk College
1501 State Hwy. 78
Kewanee, IL 61443

Centro Tecnico Indura Limitada
Camino a Melipilla #7060
Casilla 13850 Correo 21
Cerrillos, Santiago, R.M. 9201355, Chile

Gulf Technical and Safety Training Centre LLC
PO Box 25159, Abu Dhabi, UAE

Membership Counts

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New AWS Supporters

J uly 31 is the deadline for submitting your nominations for the Image of Welding Awards. You may submit your nominations online at http://awssection.org/index.php/forms/iow, or download the form and mail your nomination.

The Image of Welding Awards are issued in each of seven categories to recognize individuals and organizations that have shown exemplary dedication to promoting the image of welding in their communities.

The categories are:

- **Individual** (yourself or other person)
- **Section** (AWS local Section)
- **Large Business** (200 or more employees)
- **Small Business** (less than 200 employees)
- **Distributor** (of welding products)
- **Educator** (welding instructor)
- **Educational Facility** (for welder training)

Nominations will be judged by the Welding Equipment Manufacturers Committee (WEMCO). This committee is composed of executives of welding industry suppliers who have a mission to promote the welding equipment market. Enhancing the image of welding as a critical industry is among its priority programs.

The winners will be announced at the Image of Welding Awards Ceremony to be held during the FABTECH International & AWS Welding Show, Oct. 6–8, 2008, at the Las Vegas Convention Center in Las Vegas, Nev.

How to submit your nominations:

You may complete the form online or print and mail your nomination to AWS Image of Welding Awards, 550 NW LeJeune Rd., Miami, FL 33126.

Questions? Call AWS at (800/305) 443-9353, ext. 416.
District 1
Director: Russ Norris
Phone: (603) 433-0855

CENTRAL MASS.-RHODE ISLAND
April 4
Activity: Welding students from Old Colony Regional Vo Tech High School, Rochester, Mass., traveled to Assabet Valley Regional Technical High School in Marlborough, Mass., to participate in demonstrations of blacksmithing skills presented by metal fabrication instructors Neil Mansfield, Mark Chludenski, and George Aziz.

MAINE
April 19
Activity: The Section hosted exams for 26 members seeking Certified Welding Inspector 9-year recertifications and ASME endorsements at Holiday Inn — West, in Portland, Maine. A family affair, District 1 Director Russ Norris and his father, Russell, supervised the exams, while Russ’s daughter, Teila Norris, served as the B Test supervisor.

April 22
Activity: The Maine Section members visited New England School of Metal Working in Auburn, Maine. Warren Swan, head welding instructor, guided a tour of its new self-contained traveling welding facility, offering welding equipment demos and hands-on exercises in GTA, FCA, GMA, and SMA welding. The school uses the facility for specialized welder training, welder certifications, and preparing WPSs. The school is working on becoming an AWS Accredited Test Facility.

District 2
Director: Kenneth R. Stockton
Phone: (732) 787-0805

NEW JERSEY
April 15
Speaker: William B. Heins, program manager, materials and weld training
Affiliation: Northampton C. C.
Topic: Welding in the shadow of Bethlehem Steel
Activity: The slate of nominees for incoming officers was approved. Awards were presented to Vince Murray, Don Smith, William Heins at the April 15 New Jersey Section program.

Shown are the attendees at the Central Massachusetts/Rhode Island Section’s program.

Teila Norris and Russell Norris, her grandfather, proctored the Maine Section’s CWI exams.

Dave Griep (left) is shown with speaker William Heins at the April 15 New Jersey Section program.

Neil Mansfield demonstrates his blacksmithing skills for Old Colony and Assabet Vo Tech welding students at the Central Massachusetts-Rhode Island Section program held in Marlborough, Mass.

Shown April 22 during the Maine Section tour are instructors Ron Guimond (left) and Warren Swan.
Dave Griep, Jim Dolan, Bob Wlazlowski, and Jeff Wiswesser, George Sheehan, students’ activities chair, reported that he is completing preparations for this year’s SkillsUSA competition. Bob Petrone will proctor this year’s CWI seminar and exam in Newark, N.J., Oct. 26–Nov. 1.

NEW JERSEY-PHILADELPHIA
May 3
Activity: The New Jersey Section members joined with Philadelphia Section members to host the SkillsUSA competition at Somerset Vocational High School in Bridgewater, N.J. Eighteen students competed in the welding competition and 12 students participated in the ornamental ironwork contest. The awards-presentation ceremony was held at the New Jersey Convention Center in Somerville, N.J.

NEW YORK
April 7
Speaker: Bob Waite, P.E.
Affiliation: B. Waite Welding Engineer Consultant Co.
Topic: Torch safety tips
Activity: The meeting was held at Buckleys Restaurant in Brooklyn, N.Y.

PHILADELPHIA
April 28
Speakers: Frik Hefer, R&D director; and Randy Dry, field service director
Affiliation: Orgo-Thermit, Inc.
Topic: Explanation of the thermite welding process used to join railroad rails
Activity: This students’ night program was attended by 22 students, four welding instructors, seven board members, and District 2 Director Ken Stockton. Following the talks, the group reassembled outside to watch Hefer and Dry demonstrate the joining of two rail sections using the thermite process. The program was held at Gloucester County Institute of Technology in Sewell, N.J.
District 5
Director: Steve Mattson
Phone: (904) 260-6040

ATLANTA
MARCH 20
Speaker: Carl Matricardi, Section chair
Affiliation: WeldingSolutions, Inc., owner
Topic: Case study of a billboard collapse caused by weld failure
Activity: The Section is working with its members driving in from the Macon, Ga.,

annual AWS Carolina-Virginia welding competition at Rowan-Cabarrus C. C. (RCCC), in Salisbury, N.C. Eight schools participated in the contest that tested GMA and GTA welding, blueprint reading, plasma arc cutting, and fabrication skills. The project was to assemble and weld a model train engine. The judging was performed by both industrial welding engineers and AWS Certified Welding Inspectors. Local and national companies contributed many fine prizes. Brandon Hoffner, a RCCC welding instructor, facilitated the event. The winners were Chucki Creech, Jason Hill, Jesse Ellis, Jared Mangaro, Alec Smith, Leo Melton, Aaron Dunn, and Tony Vance.

New York Section members posed for a group shot during their April meeting.

Shown at the Reading Section program are (from left) Vice Chair Ed Yanowski, speaker Bill Cotton, Chair Joe Young, Andrew Raugh, Peter Shaub, and Treasurer Dave Hibshman.

Instructor Brandon Hoffner (right) congratulates Chucki Creech on winning first place in the Northeastern Carolina Section welding competition.

Joe Young receives a certificate of appreciation for serving as Reading Section chairman from Secretary Merilyn McLaughlin at the April program.

First-place winners in the Reading Section contest are (from left) Austin Chavous, Alex Ferrara, and Isaiah Roeder.
Area to charter a new Section closer to Macon. The meeting was held at Sidney Lee Welding Supply in Hampton, Ga.

APRIL 9
Activity: Wayne Engeron, Engeron Technology Group, presented a seminar on brazing metals and alloys. The program was held at Dekalb Technical College in Clarkston, Ga.

FLORIDA WEST COAST
APRIL 19
Activity: The Section hosted its annual Shrimp-a-Roo outing for more than 100 members and guests at Sons of Italy Lodge in Tampa, Fla. Highlights included a live band, door prizes, and a wide variety of foods. R. C. Urbanski received his AWS Life Membership Certificate Award for 35 years of service to the Society, and Eric K. Bigham received his Silver Membership Certificate Award for 25 years of service. The event organizers included Special Events Chair Eric Bigham and Chairman Al Sedory.

SOUTH CAROLINA
APRIL 17
Speaker: Bryan Howard, gas specialist Affiliation: Praxair Topic: Bulk and microbulk gas storage, safety, and economics Activity: The Section held its election of officers for the 2008–2009 term. The meeting was held at Trident Technical College in North Charleston, S.C. Also representing Praxair at the program were David Orr and Richard Temple.

District 6
Director: Neal A. Chapman Phone: (315) 349-6960

District 7
Director: Don Howard Phone: (814) 269-2895
COLUMBUS

FEBRUARY 21
Speaker: Gordon Smith
Affiliation: GE Super Abrasives
Topic: Diamonds — Their history, formation, production, and industrial applications
Activity: The Section hosted a St. Valentine’s banquet and dance program for members, students, and their guests. The event was held at Arlington Café in Columbus, Ohio.

APRIL 17
Speaker: Bill Hamilton
Affiliation: AlcoTec Wire Corp.
Topic: Hot cracking in aluminum welds
Activity: This Columbus Section program was held at Arlington Café in Columbus, Ohio.

MAY 8
Speaker: Bill Bruce
Affiliation: CC Technologies, Inc.
Topic: Essential elements of an in-service welding program
Activity: This Columbus Section program was held at Arlington Café in Columbus, Ohio.

HOLSTON VALLEY

APRIL 23
Activity: The Section hosted its fourth annual students’ night program at Tennessee Technical Center in Surgoinsville, Tenn. Jerry Sullivan, welding instructor, organized the event. Highlights included a welding skills contest with 27 students competing in high school and tech school categories, and a barbecue dinner prepared by the Tech Center staff. The top welders were Adam Vest, Chris Canter, Chad Ramey, and Adam Duncan.

GREATER HUNTSVILLE

MARCH 20
Activity: The Section members toured Pinnacle Mfg. Co., LLC, in Boaz, Ala., to study the manufacture of storage containers used in the oil industry. Leading the tour were Controllers Jason Satterfield and Joby Satterfield.

THE TOP SCORERS IN THE HOLSTON VALLEY SECTION’S WELDING CONTEST ARE (FROM LEFT) ADAM VEST, CHRIS CANTER, CHAD RAMEY, AND ADAM DUNCAN.

ATTENDEES AT THE HOLSTON VALLEY STUDENTS’ NIGHT PROGRAM POSED FOR A GROUP SHOT.

SHOWN AT THE APRIL 17 COLUMBUS SECTION PROGRAM ARE CHAIR KEVIN CLEAR (LEFT) WITH SPEAKER BILL HAMILTON.

COLUMBUS SECTION CHAIR KEVIN CLEAR (LEFT) PRESENTS A SPEAKER GIFT TO GORDON SMITH AT THE FEB. 21 MEETING.

REPUBLIC OF KOREA

APRIL 8
Activity: The Section hosted a Kansas City chapter meeting at the Binghamton Public Library. The event featured a presentation on the history of welding in South Korea. The Section also discussed future events and plans.

ST. LOUIS

MARCH 20
Activity: The Section hosted a welding demonstration at the St. Louis Technical College. The event featured a welding demonstration by an industry expert and a discussion on the latest welding technology.

Showen at the April 17 Columbus Section program are Chair Kevin Clear (left) with speaker Bill Hamilton.

Students studied welding demonstrations during the Northeast Tennessee Section’s program held at Tennessee Technology Center.

NORTHEAST TENNESSEE

APRIL 15
Activity: The Section hosted a students’ day program at Tennessee Technical College in Knoxville, Tenn. About 130 students participated in the event. Presentations were given by Jeff Hankins, Susan Smith, Wayne Summers, Gary Lancaster, Chris Griffey, Chandy Hensley, Derek Green, and others. The event included a welding skills contest, a barbecue dinner, and a panel discussion on the future of welding.

District 8

Director: Joe Livesay
Phone: (931) 484-7502

GREATER HUNTSVILLE

MARCH 20
Activity: The Section members toured Pinnacle Mfg. Co., LLC, in Boaz, Ala., to study the manufacture of storage containers used in the oil industry. Leading the tour were Controllers Jason Satterfield and Joby Satterfield.

ATTENDEES AT THE HOLSTON VALLEY STUDENTS’ NIGHT PROGRAM POSED FOR A GROUP SHOT.

THE TOP SCORERS IN THE HOLSTON VALLEY SECTION’S WELDING CONTEST ARE (FROM LEFT) ADAM VEST, CHRIS CANTER, CHAD RAMEY, AND ADAM DUNCAN.

COLUMBUS SECTION CHAIR KEVIN CLEAR (LEFT) PRESENTS A SPEAKER GIFT TO GORDON SMITH AT THE FEB. 21 MEETING.

COLUMBUS SECTION CHAIR KEVIN CLEAR (LEFT) PRESENTS A SPEAKER GIFT TO GORDON SMITH AT THE FEB. 21 MEETING.
The organizations represented included Oak Ridge H.S., Miller-Motte T.C., Plumbing & Steamfitters Union, Navy Career Center, Sheet Metal Workers Union, Tennessee Career Center, and Workforce Connections Youth Programs. The event concluded with a tour of the facility featuring demonstrations in each area, including welding, auto body technology, refrigeration, machine tool, and drafting technologies. Welding instructor Jeff Hankins, Oak Ridge H.S., organized the program.

**District 9**
**Director:** George D. Fairbanks  
**Phone:** (225) 473-6362

**MOBILE**
**APRIL 10**
**Speaker:** Bradley Byrne, chancellor  
**Affiliation:** Alabama Board of Education  
**Topic:** Progress in the two-year system in Alabama  
**Activity:** Chairman Randy Henderson presented William Todd Donald the Section Private Sector Instructor Membership Award, Lindsey LeBlanc the Section Membership Award, and James Smith the District Educator Award. The meeting was held at Saucy-Q Bar B Que in Mobile, Ala.

**NEW ORLEANS**
**APRIL 22**
**Speaker:** Mark Foret  
**Affiliation:** Northrop Grumman Ship Systems, Avondale, La.  
**Topic:** New designs in shipbuilding  
**Activity:** Following the talk, the 55 attendees took a shop tour and watched a demonstration of the submerged arc welding process. Travis Moore, Section chair, presented a sponsor-appreciation award to Roy Scott, representing Northrop Grumman Ship Systems, donor of the door prizes. The program was held at Industrial Welding Supply in Boompstown, La.

**District 10**
**Director:** Richard A. Harris  
**Phone:** (440) 338-5921

**NW PENNSYLVANIA**
**APRIL 8**
**Activity:** The Section participated in an oxyfuel safety seminar conducted by Paul Shields, district sales manager for The Harris Products Group. The program, held at Tristate Business Institute in Erie, Pa., attracted 101 attendees. District 10 Director Richard Harris presented Steve DeHart, a past Section chairman, with an appreciation award for his contributions to the Section.
DETROIT
MAY 15
Activity: The Section hosted Sheet Metal Welding Conference XIII at Schoolcraft College. Mike Palko, Ford Motor Co., chaired the event. This biennial event provides welding professionals a unique opportunity to discuss the challenges and advances in the sheet metal welding field. The proceeds benefit the Section’s scholarship fund. Earlier, at the same facility, the Section conducted a high school welding contest at Schoolcraft College. The Section awarded $4500 in scholarship funds to the winners. Taking top honors were David Woller, Neil Marshall, and Demarco Hunt.

NORTHWEST OHIO
APRIL 3
Activity: The Section members attended a motor vehicle materials and processes program held at Owens C.C. in Perrysburg, Ohio. More than 20 racing and pulling-type vehicles were on display. Karl Hoes, a Lincoln Electric welding school instructor, explained what materials and welding processes were used in each vehicle’s construction. The University of Toledo, University of Northwestern Ohio at Lima, and Bowling Green State University had vehicles on display. More than 500 people attended the event.

MAY 7
Speaker: Theresa Pollick, public information officer
Affiliation: Ohio DOT
Topic: Current and future projects for district highways
Activity: This was the Northwest Ohio Section’s old timers’ and awards banquet held at H. J’s Prime Cut in Toledo, Ohio. William McCleese was awarded his Silver Membership Certificate for 25 years of service to the Society.

Whitmer Career Tech Center
Student Chapter
MAY 5
Activity: Matt Haubert was presented the AWS Student Chapter Member Award by Craig Donnell, Chapter advisor. See photo on page 62.

DISTRICT 12 Conference
MAY 9
Activity: Representatives from each of the District 12 Sections met at Marshall Erdman & Associates, Inc., in Madison, Wis. Participating were District 12 Director Sean Moran, Dan Crifase, Craig Wentzel, Dave Ramseur, Nick Freiburg, Cory Satka, Jim Harrison, Ray Connelly, Ken Karowski, Chuck Frederick, Jerry Blaski, and Jeff Weber, AWS associate executive director.

LAKESHORE
APRIL 10
Speaker: Duane Miller, manager, engineering services
Affiliation: The Lincoln Electric Co.
Shown at the Lakeshore Section program are (from left) Sean Moran, District 12 director; James Hoffman, Section chairman; scholarship recipients Jason Staral, Bradley Bruseth, and Matthew Kent; Hildegard Baumann; welding instructor John Schaefer; and Ben Mueller, retired welding instructor.

Shown at the Lakeshore Section clay shoot outing are (from left) Secretary Dave Ramseur, Steve Miller, Lee Levenhagen, Milt Kemp, Jim King, Steve Miller Jr., Dan Jochman, Bill Krcma, Andy Miller, and Jim Becker.

Shown at the March 19 Madison-Beloit Section program are (from left) Jeff Alsip, Bill Dawson, Burt Wheeler, Chairman Ben Newcomb, Nicole Karlen, Jim Harrison, Dave Diljak, Jim Pfeil, Paul Elmer, David Burrow, speaker Ann Grevenkamp, and Jerry Hemmerling.

Shown at the April 16 Madison-Beloit Section program are (from left) Bryan Kwapis, Jim Pfeil, Jim Harrison, Bill Dawson, Dave Diljak, District 12 Director Sean Moran, and Chairman Ben Newcomb.

Topic: Design and weldability of high-strength steels
Activity: The Section presented its Rudy Baumann Ben Mueller Scholarship Awards to Jason Staral, Bradley Bruseth, and Matthew Kent, students at Lakeshore Technical College. The meeting was held at Water’s Edge Restaurant in Two Rivers, Wis.

APRIL 26
Activity: The Lakeshore Section held a sporting clay shoot outing for its last meeting event for the year. The members met at Triple J Game Farm and Sporting Clays in Reedsville, Wis., to test their skills and enjoy dinner. The windy conditions and cold temperature made the event a challenge for even the best shooters. The door prizes were donated by local welding equipment suppliers.

MADISON-BELOIT
MARCH 19
Speaker: Ann Grevenkamp, compliance officer, industrial hygienist
Affiliation: OSHA
Topic: Update on the OSHA hexavalent chromium guidelines
Activity: The program was held at Coliseum Bar in Madison, Wis.

APRIL 16
Speaker: Sean Moran, District 12 director
Affiliation: Miller Electric Mfg. Co., product manager
Topic: Benefits of AWS membership
Activity: This Madison-Beloit Section program was held at Coliseum Bar in Madison, Wis.

MILWAUKEE
APRIL 17
Activity: The Section members toured Super Steel Corp. in Milwaukee, Wis., to study its operations. The company designs, builds, and delivers passenger and freight railroad locomotives, agricultural equipment, and other heavy industrial equipment. Featured is the company’s extensive welder training program detailed by Chris Nielsen, senior welding engineer. Keith S. Trafton, CEO and president, conducted the tour.

MAY 15
Activity: The Milwaukee Section members toured the Trek Bicycle Co. in Waterloo, Wis., to study the manufacture of high-end carbon-fiber and aluminum bikes. Karen Gilgenbach, Section vice chair, presented scholarship awards to Terry Herman, Michelle Freeman, Joseph Chaney, Dmitri Sasic, and Bobbi Bishofberger. The dinner was held at Pine Knoll Restaurant in Lake Mills, Wis. Forty-six members and guests attended.
Activity: The Section members toured CNH Global plant in Racine, Wis., to study its methods for manufacturing and assembling farm tractors.

RACINE-KENOSHA
May 7
Activity: The Section members toured CNH Global plant in Racine, Wis., to study its methods for manufacturing and assembling farm tractors.

District 13
Director: W. Richard Polanin
Phone: (309) 694-5404

CHICAGO
April 5
Activity: The Section hosted a CWI exam. Jeff Stanczak received the District Meritorious Certificate Award from Eric Krauss.

April 16
Activity: Pete Host discussed welding and careers in welding for students at the College of DuPage in Glen Ellyn, Ill.

J.A.K.
April 20
Activity: The Section hosted an awards-presentation ceremony in Kankakee, Ill., hosted by Secretary Ziad Awad. Other business included preparing for the second annual Kankakee Area Career Center welding competition. Chairman John Willard received an appreciation award for his contributions to the Section.

Logan Wojcik recently joined the Racine-Kenosha Section as a Student Member.

Shown at the Milwaukee Section tour are Chairman Jerry Blaski (center) with Super Steel welding engineer Chris Nielsen (left) and CEO Keith Trafton.

Shown at the May Milwaukee Section program are (from left) Scholarship Chair Craig Wentzel, Joseph Chaney, Dmitri Sasic, Bobbi Bishopberger, Terry Herman, Michelle Freeman, and Vice Chair Karen Gigenbach.

Ziad Awad (right) is shown with John Willard, chairman of the J.A.K. Section.

Jeff Stanczak (left) is shown with Eric Krauss at the Chicago Section program in April.
Shown at the J.A.K. Section program are (from left) Chairman John Willard, Vice Chair Bryce Kale, SENSE director Mike Spangler, and Secretary Ziad Awad.

Brian Farkas discussed welding aluminum alloys for the Indiana Section members.

The first-place winners in the Indiana Section’s Mid-West Team Welding Tournament are (from left) Phillip Robertson, Brandon Newton, R. J. Corbett, Charles Ayers, and Clifton Miracle.

Shown judging the Indiana state SkillsUSA welding contest are Gary Tucker (left) and Dick Alley, an AWS past president.

ST. LOUIS
APRIL 17
Activity: The Section hosted its annual students’ night program at Ranken Technical College in St. Louis, Mo. The speakers included Ted Stegman, president of Industrial Steel Fabricators, and Glen Kayser, plant manager at Custom Fabricators & Coatings. The talks featured welding career opportunities and benefits available in the St. Louis area. Five $900 scholarships were presented to local college students. Eight outstanding students were recognized with a certificate and a 4½-in. grinder. Their welding instructors were on hand to present the awards and give talks on why their students were chosen to receive the honors.

TRI-RIVER
APRIL 29
Speaker: Lloyd Benson
Affiliation: Airgas, sales representative (ret.)
Topic: Cutting torch maintenance and repairs
Activity: John Bockhorst, Southern Indiana Career and Vocational School, discussed the latest changes to the welding program offered at the center. The meeting was held at Evansville Armature in Evansville, Ind.

District 15
Director: Mace V. Harris
Phone: (651) 287-3267

NORTHWEST

NOVEMBER 2007
Activity: The Section hosted a round-table discussion on welding certification. District 15 Director Mace Harris was the moderator. Participating were Bob Sands, a MIL specs expert; Bruce Danielson, discussing D1.1 Code provisions; and Dwight Affeldt presenting on the ASME standards.

JANUARY
Activity: The Northwest Section members toured Nelson Stud Welding in Bloomington, Minn. Tour guides included Bob Shuster, Keith Zelinga, and Don Merker.

MARCH
Activity: The Northwest Section members participated in and provided 20 judges for the Minnesota SkillsUSA competition. The event involved 49 contestants. The postsecondary class winner was Tony Nelson; Colten Milford won the secondary class.

District 16
Director: David Landon
Phone: (641) 621-7476

CENTRAL NEBRASKA-MID-PLAINS

APRIL 17
Activity: Members of the Mid-Plains and

KANSAS CITY

APRIL 10
Speaker: Jason Mueller, welding instructor

Dennis Wright (right), Kansas City Section chair, receives an award from Vice Chair Brian McKee at the April meeting.
Affiliation: Johnson County C.C.
Topic: Johnson County C.C. welding courses offered for railway contractors
Activity: The Section held its election of officers. Dennis Wright received an appreciation award for his services as chairman. The meeting was held at Johnson County C.C. in Overland Park, Kan.

MAY 1
Speaker: David Landon, District 16 director
Affiliation: Vermeer Mfg., manager, welding engineering
Topic: Lean manufacturing techniques
Activity: This Kansas City Section program was held at KC Masterpiece Barbecue and Grill in Kansas City, Mo.

NEBRASKA
MAY 17
Activity: Sixty-four Section members competed in the 14th annual golf outing held at Eagle Hills Golf course in Omaha, Neb.

CENTRAL ARKANSAS
APRIL 14–16
Activity: The Section members worked with representatives from United Association of Plumbers and Pipefitters Local #155 and Lincoln Electric Co. on the state SkillsUSA welding, plate cutting, and pipe welding competitions. The participants were Matt Fair, UA business manager; Tim Ryan, UA financial secretary; Jimmy Brewer, UA field representative; Bob Hlass, Lincoln Electric; and Section Chair Dennis Pickering. The event was held at Arkansas Career Training Institute in Hot Springs, Ark.

EAST TEXAS
APRIL 24
Speaker: Larry Richardson, QA director
Barry Lawrence (left), outgoing Tulsa Section chair, is shown with incoming Chairman Jamie Pearson.

Affiliation: Hi-Tech Testing, Longview, Tex.
Topic: The latest technology in radiographic testing
Activity: Bill Kielhorn, Section secretary and treasurer, accepted his Gold Membership Certificate Award for 50 years of service to the Society from East Texas Section Chairman Bryan Baker. The program was held in Longview, Tex.

NORTH TEXAS
APRIL 15
Speaker: Ernest Levert, AWS past president
Affiliation: Lockheed Martin, senior staff manufacturing engineer
Topic: Recent advancements in materials-joining technology
Activity: The Section is active in supporting the local food bank. Rob Tessier, Section chair, presented Levert with the Section’s custom desk clock speaker gift. More than 100 members and guests attended the program. The meeting was held at Spring Creek Barbecue in Irving, Tex.

TULSA
APRIL 22
Activity: The Section members toured the Matrix Service facilities in Port of Catoosa, Okla., to study the company’s shape cutting, beveling, and welding of storage tanks, and tank plate rolling and beveling operations. Mark Hall and Darian Erstad conducted the program. Barry Lawrence was presented an appreciation award for his services as chairman. Incoming Chair Jamie Pearson was presented the District Private Sector Instructor Membership Award.

District 18
Director: John Bray
Phone: (281) 997-7273
HOUSTON
APRIL 16

Recognized for serving as trainers in the Houston Section’s Instructors Institute are (from left) Sid Tweetle, Chair John Husfeld, Jonathon Davis, and Justin Calugar.

Shown during the Houston Section tour of Greens Bayou Pipe Mill on April 25 are (from left) Daniel Brotsch, Tim Bailey, Martha Moreno, Daryl Wilson, Julie Theiss, Ron Theiss, Cristina Colon, Derek Stelly, tour guide Steve Buckles, and Tom Danowski.

Speaker: Steve Buckles, production manager
Affiliation: Greens Bayou Pipe Mill
Topic: Manufacturing structural steel pipe using API 2B standards
Activity: Section appreciation plaques were presented to the trainers who participated in the recent Instructors Institute event. Cited were Sid Tweetle with Miller Electric; Chairman John Husfeld; and Jonathon Davis and Justin Calugar with Lincoln Electric. The program was held at Brady’s Landing in Houston, Tex.

APRIL 24
Activity: The Houston Section hosted its annual golf outing at Tour 18 Golf Course in Humble, Tex. About 70 members and guests participated in the event.

Speaker Steve Buckles (left) is shown with John Husfeld, Houston Section chair, during the April 16 program.
JULY 2008

Activity: The Houston Section members toured Greens Bayou Pipe Mill in Houston, Tex. Steve Buckles, production manager, conducted the program.

BRITISH COLUMBIA

FEBRUARY 19
Speaker: Tim Cooper, professor
Affiliation: University of the Fraser Valley
Topic: Economic and technical “fixes” for the impact of global warming effects
Activity: The Section hosted a raffle of items donated by industry sponsors. The proceeds were contributed to the scholarship fund. The meeting was held at new Westminster, B.C., Canada.

MARCH 20
Speaker: Martin Gagne, manager, Sorelmetal Technical Services
Affiliation: Rio Tinto Iron and Titanium
Topic: Welding ductile iron to steel
Activity: The British Columbia Section members participated in a joint meeting hosted by the American Foundry Society (AFS). Eric Hasselmann, AFS vice chair, conducted the program.

APRIL 15
Activity: The British Columbia Section members toured Brenco Industries, Ltd., in Surrey, B.C. Steve Heim, president, and chairman of the Fabricators & Manufacturers Assn., Int’l, presented a talk on the various cutting, metal forming, and fabrication processes used in the facility, then conducted a tour of the shop areas.

NORTHERN ALBERTA

MARCH 26
Speaker: Cal Blakney, owner
Affiliation: Edmonton Cast Iron Repair Co.
Topic: Repair of cast iron
Activity: More than 50 members and guests attended this program, held at the University of Alberta Faculty Club in Edmonton, Alb., Canada.

APRIL 16
Speaker: Matthew Yarmuch, Section chair
Affiliation: Alberta Research Council
Topic: Plasma transferred arc welded overlays for wear and corrosion resistance
Activity: Following the talk, Yarmuch guided the 55 attendees on a tour of the Alberta Research Council facilities in Edmonton, Alb., Canada. Ken Nelson, a past Section chair, presented Yarmuch with a speaker gift. Student Patrick Kerr won the door prize, a copy of Welding Handbook. Fifty-five members and guests attended the program.

District 19
Director: Neil Shannon
Phone: (503) 201-5142

District 20
Director: William A. Komlos
Phone: (801) 560-2353

Tim Cooper discussed the impacts of global warming for the British Columbia Section in February.

Student Patrick Kerr (right) is shown with Northern Alberta Section Chair Matthew Yarmuch during the April 16 program.

Steve Heim conducted a tour of Brenco Industries for the British Columbia Section in April.

Speaker Cal Blakney (left) is shown with Matthew Yarmuch, Northern Alberta Section chair, at the March 26 meeting.

Northern Alberta Section Chair Matthew Yarmuch (left) accepts a speaker gift from Ken Nelson at the April 16 meeting.

Eric Hasselmann (left), AFS vice chair, presents a speaker gift to Martin Gagne at the joint American Foundry Society and AWS British Columbia Section meeting in March.

District 19

District 20
COLORADO
MAY 8
Activity: The Section members met at Colorado School of Mines in Golden, Colo., to learn about its Center for Welding, Joining, and Coating Research. Prof. Patricio Mendez presented an overview of the Center, then guided a tour of the facility. Students gave presentations and demonstrations on orbital welding and thermit welding. The Section held its election of officers, chaired by Dean Mitchell, vice chairman.

LONG BEACH-ORANGE COUNTY
APRIL 17
Speaker: Gene E. Lawson, AWS president
Affiliation: ESAB Welding & Cutting
Topic: A changing welding environment creates new opportunities
Activity: Section scholarships were presented to students Josh Hurst, Brent Helmick, and Justin Nichols. Richard Hutchison, outgoing chairman, received a certificate of appreciation for his services. Cary Chiu was introduced as the Section’s incoming chairman. Ben Anderson accepted a certificate on behalf of Summit Gas and Gear for hosting the meeting and providing the raffle prizes and food.

Lou DeFreitas (left) is shown with Dale Flood, District 22 director, at the Santa Clara Valley Section program.

Speaker Gordon Gibbs (right) is shown with Antonio De Sousa at the Santa Clara Valley Section program.

Patricio Mendez (wearing a tie) and Colorado School of Mines students demonstrated orbital welding and thermit welding for the Colorado Section members.
District 22
Director: Dale Flood
Phone: (916) 933-5844

FRESNO
APRIL 17
Activity: The Section members toured the Chris Sorensen Studio in Fresno, Calif. Chris Sorensen creates some of his art works using scrap metal, plasma arc cutting, and a welding torch. Tour highlights included demonstrations of various welding and blacksmithing techniques for building artistic metal sculptures. Bernard Heer, Frank Jackson, and Robert Rorick demonstrated their blacksmithing skills. Bob Gifford described how he built his sculpture of a fountain using gas metal arc welding.

SAN FRANCISCO
MAY 7
Speaker: George Vander Voort, director of research and technology
Affiliation: Buehler, Ltd.
Topic: Studying crystal structures of metals using color metallography
Activity: The Section displayed a new Epson digital projector, purchased with the funds saved from reduced printing and mailing costs effected by increased use of e-mail. September 3 was designated as past chairmen’s night, to be held at Spenger’s Restaurant in Berkeley, Calif. For information, call Chairman Tom Smeltzer, (707) 253-3237.

SANTA CLARA VALLEY
MAY 13
Speaker: Gordon Gibbs
Affiliation: Sandia National Laboratories
Topic: Electron beam profiling as a tool
Activity: The Section hosted its annual College of San Mateo night activities. A special recognition was given to Lou DeFreitas by District 22 Director Dale Flood. The two presented the new Section banner.
Member-Get-A-Member Campaign

Listed are the members participating in the 2007–2008 AWS Member-Get-A-Member Campaign for the period between June 1, 2007, and May 31, 2008. For campaign rules and a prize list, see page 65 of this Welding Journal. Standings are as of 5/19/2008. If you have any questions regarding your member proponent points, call the Membership Department, (800) 443-9353, ext. 480.

Winner’s Circle
Members who have sponsored 20 or more new Individual Members, per year, since June 1, 1999. The superscript indicates the number of times the member has achieved Winner’s Circle status.
J. Compton, San Fernando Valley7
E. Ezell, Mobile5
J. Merzthal, Peru5
G. Taylor, Pascagoula2
B. Mikeska, Houston1
G. Taylor, Pascagoula2
J. Merzthal, Peru2
E. Ezell, Mobile5
L. Taylor, Pascagoula
B. Mikeska, Houston1
G. Taylor, Pascagoula2
J. Merzthal, Peru2
E. Ezell, Mobile5

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AWS Members sponsoring 1 or 2 new Individual Members. Only those sponsoring 2 AWS Individual Members are listed.
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M. Beaton, North Texas
C. Bridwell, Ozark
D. Campbell, North Texas
D. Daugherty, Indiana
S. Fetters, Johnstown-Altoona
W. Galvery Jr., Long Beach/Or. County
C. Gotangco, New Orleans
J. Hoffm an, Lakeshore
H. Jackson, L.A./Inland Empire
C. Johnson, Northern Plains
J. Johnson, Northern Plains
R. Key, San Antonio
J. Kozeniecki, Milwaukee
D. Landon, Iowa
S. Leighton, Louisville
J. Livesay, Nashville
J. McCarty, St. Louis
J. Nieto, Corpus Christi
R. Norris, Maine
R. Panter, Long Bch./Or. Cty.
J. Reid, Boston
F. Schmidt, Niagara Frontier
G. Sinkule, Northern Michigan
T. Snider, Mobile
A. Sumal, British Columbia
J. Truitt, San Diego
J. Wagner, Kansas City
R. Wright, San Antonio
M. Yarmuch, Northern Alberta
P. Zammit, Spokane

President’s Guild
Members sponsoring 20 or more new Individual Members.
L. Taylor, Pascagoula — 144
E. Ezell, Mobile — 23

President’s Roundtable
AWS Members sponsoring 9–19 new Individual Members.
J. Compton, San Fernando Valley — 16
J. Hope, Puget Sound — 12
J. Sanchez, Cuauitlitan Icazali — 9
W. Wood, Baltimore — 9

President’s Club
AWS Members sponsoring 3–8 new Individual Members.
R. Cook, Utah — 8
S. Christensen, Nebraska — 7
R. Ellenbecker, Fox Valley — 7
D. Wright, Kansas City — 7
A. Castro, South Florida — 6
A. Demarco, New Orleans — 5
V. Raloff, J.A.K. — 5
P. Johnson, Houston — 4
K. Kotter, Utah — 4
T. Lowe, Northwest Ohio — 4
T. Moffitt, Tulsa — 4
R. Gaffney, Tulsa — 3
L. Garner, Mobile — 3
C. Gilbert, East Texas — 3
P. Hanley, Peoria — 3
T. Nielsen, Pittsburgh — 3

Student Member Sponsors
Members sponsoring 4 or more new AWS Student Members.
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D. Berger, New Orleans — 38
M. Reiter, Columbus — 36
J. McCloud Jr., Puget Sound — 35
G. Euliano, Northwestern Pa. — 34
R. Evans, Siouxland — 34
D. Nelson, Puget Sound — 34
T. Zablocki, Pittsburgh — 28
M. Anderson, Indiana — 26
R. Hutchison, Long Bch./Or. Cty. — 23
N. Goncalo, Milwaukee — 21
R. Hutchison, Long Bch./Or. Cty. — 20
G. Smith, Lehigh Valley — 20
J. Daugherty Louisville — 19
G. Seese, Johnstown-Altoona — 19
B. Mikeska, Houston — 19
J. Kacir, Detroit — 18
C. Kipp, Lehigh Valley — 18
D. Parker, Idaho-Montana — 18
D. Ketter, Willamette Valley — 17
M. Arand, Louisville — 16
J. Ciaramitaro, N. Central Florida — 16
T. Bridgum, Northwest — 15
J. Compton, San Fernando Valley — 15
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T. Moore, New England — 15
D. Roskiewich, Philadelphia — 15
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H. Browne, New Jersey — 14
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C. Overfelt, SW Virginia — 14
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A. Wyatt, Holston Valley — 13
T. Buchanan, Mid-Ohio Valley — 12
J. McCarty, St. Louis — 12
R. Mumms, Utah — 12
B. Suckow, Northern Plains — 12
D. Zabel, Southeast Nebraska — 12
M. Rotary, Rotary — 11
W. Harris, Pascagoula — 10
D. Lynn, Ozark — 10
S. Robeson, Cumberland Valley — 10
R. Tully, San Francisco — 10
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W. Troutman, Cleveland — 7
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550 NW LeJeune Rd., Miami, FL 33126
www.aws.org  phone (800/305) 443-9353; FAX (305) 443-7559
(Phone extensions are shown in parentheses.)

AWS PRESIDENT
Gene E. Lawson
glawson@esab.com
ESAB Welding and Cutting
25108 Marguerite Pkwy. #165
Mission Viejo, CA 92692

ADMINISTRATION
Ray W. Shook..rwshook@aws.org . . . . . . . . . . . . . . . . . . . (210)
CFO/Deputy Executive Director
Frank R. Tarafa..ftaraf@aws.org . . . . . . . . . . . . . . . . . . . (252)
Deputy Executive Director
Cassie R. Burrell..cburrell@aws.org . . . . . . . . . . . . . . . . . (253)
Associate Executive Director
Jeff Weber..jweber@aws.org . . . . . . . . . . . . . . . . . . . . . . . (246)
Executive Assistant for Board Services
Gricelda Manalich..gricelda@aws.org . . . . . . . . . . . . . . . . (294)
Administrative Services
Managing Director
Jim Lankford..jlankford@aws.org . . . . . . . . . . . . . . . . . . . (214)
IT Network Director
Armando Campana..acampana@aws.org . . . . . . . . . . . . . . (296)
Director
Hidal Nuñez..hidal@aws.org . . . . . . . . . . . . . . . . . . . . . . . (287)
Database Administrator
Natalia Swain..nswain@aws.org . . . . . . . . . . . . . . . . . . . . (245)

Human Resources
Director, Compensation and Benefits
Luisa Hernandez..luisa@aws.org . . . . . . . . . . . . . . . . . . . (266)
Manager, Human Resources
Dora Shade..dshade@aws.org . . . . . . . . . . . . . . . . . . . . . . . (235)

INT’L INSTITUTE OF WELDING
Senior Coordinator
Sissibeth Lopez..sissibeth@aws.org . . . . . . . . . . . . . . . . (319)
Provides liaison services with other national and international professional societies and standards organizations.

GOVERNMENT LIASON SERVICES
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Webster, Chamberlain & Bean, Washington, D.C., (202) 466-2976; FAX (202) 835-0243. Identifies funding sources for welding education, research, and development. Monitors legislative and regulatory issues of importance to the welding industry.

Brazing and Soldering
Manufacturers' Committee
Jeff Weber..jweber@aws.org . . . . . . . . . . . . . . . . . . . . . . (246)

RWMA — Resistance Welding
Manufacturing Alliance
Susan Hopkins..susan@aws.org . . . . . . . . . . . . . . . . . . . . (295)

WEMCO — Welding Equipment
Manufacturers’ Committee
Manager
Natalie Tapley..natapley@aws.org . . . . . . . . . . . . . . . . . (444)

CONVENTION and EXPOSITIONS
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Corporate Director, Exhibition Sales
Joe Krall..jkrall@aws.org . . . . . . . . . . . . . . . . . . . . . . . . (297)
Organizes the annual AWS Welding Show and Convention, regulates space assignments, registration items, and other Expo activities.

PUBLICATION SERVICES
Department Information .......................... (275)
Managing Director
Andrew Cullison..cullison@aws.org . . . . . . . . . . . . . . (249)
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Publisher
Andrew Cullison..cullison@aws.org . . . . . . . . . . . . . . (249)
Welding Handbook
Editor
Mary Ruth Johnson..mrjohnson@aws.org . . . . . . . . . . . . . (238)
National Sales Director
Rob Saltstein..salt@aws.org . . . . . . . . . . . . . . . . . . . . . . . (243)
Society and Section News Editor
Howard Woodward..woodward@aws.org . . . . (244)

MARKETING COMMUNICATIONS
Director
Ross Hancock..rhancock@aws.org . . . . . . . . . . . . . . . . (226)
Assistant Director
Adrienne Zalkind..azalkind@aws.org . . . . . . . . . . . . . . . (416)
Webmaster
Angela Miller..amiller@aws.org . . . . . . . . . . . . . . . . . . . (456)

MEMBER SERVICES
Department Information .......................... (480)
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Cassie R. Burrell..cburrell@aws.org . . . . . . . . . . . . . . (253)
Director
Rhenda A. Mayo..mayo@aws.org . . . . . . . . . . . . . . . . . (260)
Serves as a liaison between Section members and AWS headquarters. Informs members about AWS benefits and activities.

CERTIFICATION SERVICES
Department Information .......................... (273)
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John Filippi..jfilippi@aws.org . . . . . . . . . . . . . . . . . . . . (222)
Managing Director, Technical Operations
Peter Howe..phowe@aws.org . . . . . . . . . . . . . . . . . . . . (309)
Manages and oversees the development, integrity, and technical content of all certification programs.

Director, Int’l Business & Certification Programs
Priti Jain..pjitain@aws.org . . . . . . . . . . . . . . . . . . . . . (258)
Directs all int’l business and certification programs. Is responsible for oversight of all agencies handling AWS certification programs.

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Managing Director
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Director, Education Services Administration and Convention Operations
John Ospina..jospina@aws.org . . . . . . . . . . . . . . . . . . . (462)

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Senior Manager
Wendy S. Rees..wrees@aws.org . . . . . . . . . . . . . . . . . . . (293)
Coordinates AWS awards and AWS Fellow and Counselor nominees.

TECHNICAL SERVICES
Department Information . . . . . . . . . . . . . . . . . . . . . . . . (540)
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)
Personnel and Facilities Qualification, Computerization of Welding Information

Stephen P. Hedrick..steve@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..rcnell@aws.org . . . . . . . . . . . . . . . (451)

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

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Filler Metals and Allied Materials, Int’l Filler Metals, Instrumentation for Welding, UNS Numbers Assignment

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Welding Qualification, Structural Welding

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Machinery and Equipment, Robotics Welding, Arc Welding and Cutting Processes

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Welding in Sanitary Applications, High-Energy Beam Welding, Aircraft and Aerospace, Friction Welding, Railroad Welding, Thermal Spray

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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, gmanalich@aws.org, c/o Gerald D. Uttrachi, chair, National Nominating Committee.

The next meeting of the National Nominating Committee is scheduled for October 2008. The terms of office for candidates nominated at this meeting will commence January 1, 2010.

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.

William Irrgang Memorial Award 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.

The award consists of a $2500 honorarium and a certificate. It is presented during the FABTECH International & AWS Welding Show held each fall. The award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor the late William Irrgang.

George E. Willis Award is awarded each year to an individual who promotes the advancement of welding internationally by fostering cooperative participation in areas such as technology transfer, standards rationalization, and promotion of industrial goodwill.

The award consists of a $2500 honorarium and a certificate. It is presented during the FABTECH International & AWS Welding Show held each fall. The award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor George E. Willis.

Honorary Membership Award is presented to 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. Honorary Members have full rights of membership.

National Meritorious Certificate 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.

International Meritorious Certificate Award is given in recognition of significant contributions to the welding industry for service to the international welding community in the broadest terms. The awardee is not required to be an AWS member. Multiple awards may be given. The award consists of a certificate and a one-year AWS membership.

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AWS Foundation, Inc., 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.

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Director, SOS Gulf Coast Division
Connie Bowling, ext. 308, cbowling@aws.org
550 NW LeJeune Rd., Miami, FL 33126 (305) 445-6628; (800) 443-9353, ext. 293 general information: (800) 443-9353, ext. 689; vpinsky@aws.org

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 Gene E. Lawson, as listed on the previous page.
The world of nondestructive testing is expanding due to the introduction of new technologies. Among the technologies to be discussed are several of the new versions of ultrasonic testing (UT), including time of flight diffraction (TOFD), alternating current field measurement (ACFM), phased array inspection, and guided wave examination. The ASME Code, with Code Case No. 2235, has accepted TOFD in lieu of radiography examination for thicknesses over 4 inches. ACFM is being used to detect fatigue cracks in offshore structures, and is now being used on many structures throughout industry. Both phased array and guided wave inspection are gaining in popularity. Phased array has demonstrated high speed, thorough inspection, while the guided wave approach has been especially useful in remote application situations.

In addition, attendees will hear about a new UT system that is being used to inspect austenitic welds in LNG storage tanks. This system has been accepted as an alternative to radiographic testing by the American Petroleum Institute.

Other presentations will include the use of acoustic emission to inspect the welds in bridge construction, and an introduction to a project funded by the Center for Naval Shipbuilding Technology involving a digital radiography system that uses computed radiography techniques.

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Richard Gostautas, Infrastructure Group Leader, Physical In-Service Bridges
Use of Acoustic Emission for Field Inspection of Welds for technologies for the evaluation of FSW.

A semi-automatic, first-of-its-kind, ultrasonic examination technique that is currently being utilized for the examination of the high nickel alloy welds of 9% Ni LNG tanks will be described. It is currently being utilized to examine the world’s largest LNG tanks, 190,000 m³, and will shortly be applied to a 200,000 m³ storage tank. This technique takes the volumetric examination of the shell welds off the critical path and places the welding operation in its place.

Computed Radiography – Innovations for Film Quality Results in Industrial Applications
Terry Plasek, Western Regional Manager, Fujifilm NDT Systems, Conroe, TX
This presentation addresses the evolution of computed radiography dedicated to industrial use and applications. Discussion on the improvements in systems resulting in the ability to achieve results equal to or, in some cases, better than conventional wet film radiography. System specifications and example imaging are also included.

Eddy Current Array and Ultrasonic Phased-Array Technologies as Reliable Tools for FSW Inspection
Michael Moles, Senior Technology Manager, Olympus NDT Canada, Toronto, Canada and André Lamarre, Business Development Director, Aerospace and Defense, Olympus NDT, Quebec, Canada
Ultrasonic phased-array technology has demonstrated over the years its capabilities to reliably inspect aluminum friction stir welds as many aerospace manufacturers have used it during their manufacturing process. Recent developments in eddy current array technology added new perspectives to the FSW evaluation. It is now possible to characterize the tool penetration and minimize the presence of an oxide layer, so-called kissing bond. This article will summarize results of both technologies for the evaluation of FSW.

Use of Acoustic Emission for Field Inspection of Welds for In-Service Bridges
This presentation includes a few case studies that describe and illustrate how acoustic emission monitoring was used as a NDE tool for condition assessment of defects and discontinuities (e.g. cracks) in welds on different types of in-service bridges.

Advancements in NDE at Edison Welding Institute
Kevin M. Clear, Project Engineer – NDE Technology, Edison Welding Institute, Columbus, OH
This presentation will discuss the advancements in nondestructive evaluation at Edison Welding Institute. It will provide a brief overview of linear and matrix phased array, digital computed radiography, phased array eddy current, and microwave inspection techniques.

Practical Applications of the Time of Flight Diffraction Ultrasonic Technique
David Dechene, NDE Level III for US Operations, Sonomatic, Baton Rouge, LA
Originally developed in the late 1970’s for the nuclear industry as a very accurate flaw-sizing tool, the time of flight diffraction (TOFD) ultrasonic technique has also gained popularity over the years for its other unique abilities, such as one-scan weld inspections, corrosion mapping, hydrogen damage detection, and rapid screening of vessel shells, to name a few. This presentation is designed to explain what TOFD is, how it differs from pulse echo UT, its advantages/disadvantages, and its applications for industry today.

An Introduction to Alternating Current Field Measurement
Robert E. Cameron, Manager, Quality Assurance and Training, TWI North America, LCC, Deer Park, TX
ACFM is an electromagnetic test technique used for the detection and sizing of surface-breaking cracks. It was initially conceived for use under water to detect flaws in offshore structures and proved to be very effective. Now ACFM is used to inspect structures both in and out of the water. ACFM has the advantage, over some other NDT methods, that the surface requires minimal cleaning. Also, ACFM can be applied to surfaces that are painted, or have other coatings up to about 5 mm in thickness. ACFM is used not only to detect and size surface-breaking cracks, but also to monitor crack growth.

Emerging Ultrasonic Guided Wave Applications in NDT, Structural Health Monitoring (SHM), and Weld Inspection
Joseph L. Rose, Paul Morrow Professor, Engineering Science & Mechanics Department, Pennsylvania State University, University Park, PA. Dr. Rose is also Senior Scientist, FBS Inc., Feature Based Systems, College, PA. Dr. Rose’s paper will be presented by Michael Moles, Senior Technology Manager, Olympus NDT Canada, Toronto, Canada
Ultrasonic guided waves have always been of interest for decades, but little used in NDT and SHM. Today, however, with significant advancements in theoretical understanding and computational efficiency, the road ahead for guided waves is clear. Phased array utilization has advanced guided wave applications even further. Sample problems in pipeline, aircraft, and rail will be covered, along with special emphasis on newly developed phased array scanning of an entire plate from a single sensor position and weld inspection with simple single line scan at any arbitrary distance from the weld.

American Welding Society®
The Navy Metalworking Center has released two informative two-page bulletins Laser Peening, and Naval Applications of Laser-Welded Metallic Sandwich Panels. The laser peening technique is similar to shot peening but imparts compressive stresses much deeper into the components with minimal surface deformation, using short blasts of intense laser light. The process is detailed with its benefits and several applications using mobile laser peening systems. The other bulletin details innovative lightweight sandwich panels under consideration by the U.S. Navy for significant weight and cost reductions in the construction of Navy ships. Discussed are the background on the development project, and the many benefits of using modular panel assemblies, laser welding, applications, and the vendors employed. A number of implementation successes are described for applications specifying lightweight, corrosion-resistant panels that must also meet structural, heat, and other requirements. Several photographs illustrate the welding and assembly of the sandwich panels.

Concurrent Technologies Corp.
www.nmc.ctc.com
(717) 565-4405

Laser Safety Products Pictured in Catalog
A 16-page, full-color catalog illustrates and details the company’s full line of laser safety products, literature, training courses, conferences, and services. New items include aluminum and magnetic signs at reduced prices, and updated laser safety standards and manuals. A few of the new titles include Guide for the Selection of Laser Eye Protection, ANSI Z136.7 (2008) for Testing and Labeling of Laser Protective Equipment, CLSOs’ Best Practices in Laser Safety, and Laser Safety Guide. Described are training courses, including Laser Safety Officer, and Advanced Concepts in Laser Safety, and a number of online training courses. Listed on one page are all of the company’s publications with prices. Included is complete membership information and details of upcoming conferences.

Laser Institute of America
www.laserinstitute.org
(800) 345-2737

Updated Welding Equipment Catalog Issued
The company’s 2008 product catalog illustrates and describes its updated complete lines of welding machines, wire feed-
ers, robotic solutions, consumables, fume-extraction systems, automated solutions, guns, torches, and welding equipment accessories. Each section begins with a selection guide that highlights each machine’s capabilities at a glance and allows for easy comparisons. Once users have narrowed their choices, they can turn to the color-coded product pages for more detailed information on each machine, including welding process, key features, benefits, output range, input power, dimensions, and photographs. Order a copy of the catalog by phone or visit the Web site and request Bulletin E1.10.

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

Catalog Pictures Modular Work-Holding Fixtures

A 94-page catalog illustrates the company’s line of Amflex® modular work-holding self-aligning fixture elements. Included are hydraulic and pneumatic fixtures, modular components, grids, force cartridges, tombstones, and high-density work-holding systems for dedicated or manual fixturing. Included is a variety of precision grid bases, ball elements, spring supports, V-block supports, locators, and clamping components. Detailed technical data with application information, design options, and mounting dimensions are provided.

Advanced Machine & Engineering
www.ame.com
(815) 962-6076

CD Details Welding Equipment

A CD details the company’s lines of welding equipment and welding automation products and systems providing technical data in an easy-to-use format. The CD is intended for anyone buying manual or automated welding equipment. All products are included including a portable Caddy range of arc welding machines through to heavy-duty arc welding machines and ancillary equipment, torches, components, and plasma arc cutting equipment. For automated welding, the CD details orbital gas tungsten arc welding, universal mechanization equipment, flux handling equipment, column-and-boom equipment, resistance welding, friction stir welding, and many other items. One section spotlights the company’s ability to custom-design systems to suit customers’ specific applications.

ESAB Welding & Cutting Products
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(800) 372-2123

Leak Detection and Diagnostic Tools Pictured

A 6-page, full-color brochure illustrates and describes the company’s lines of leak detection products and diagnostic tools for industrial systems. Shown are high-intensity, corded UV lamps, and cordless, rechargeable LED flashlights. Featured is the Optimax™ 365 that provides a pure, long-wave UV light that makes even dirty oil leaks glow brightly. Other tools featured include the Marksman™ ultrasonic diagnostic tool, Cobra™ series of multipurpose borescopes, and Pro-Alert™ electronic refrigerant leak detector. Information is provided on a complete line of fluorescent dyes used to detect hydraulic fluid, engine oil, compressor oil, gearbox oil, fuel, and water leaks.

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www.spectronics.com
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Free Poster Pictures Common Weld Flaws

Ten of the most common weldment problems, their likely causes, and fixes are presented in a 22- × 28-in. poster format. Using diagrams and concisely written explanations, the poster serves as a handy reference for educational welding environments and professionals too. Ten topics detailed include porous welds, cracked welds, undercutting, distortion, spatter, incomplete fusion, overlapping, insufficient penetration, magnetic arc blow, and inclusions. The free poster may be ordered by calling the number below or sending an e-mail request to the fulfillment center at databs@mindspring.com.

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www.hobartbrothers.com
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Safety Booklet stresses Importance of Standards

Safety Equipment Standards — Your Keys to Business Success gives an overview of the importance of using personal protective and safety equipment made to rigorous standards. The 12-page brochure is organized in a Q & A format with three sections that pose questions with answers about U.S. standards, international standards, and conformity assessment. Included is information on the U.S. standards system and the role of the American National Standards Institute, and the growing importance of international standards in global commerce. The free PDF version of the booklet may be downloaded from the Web site.

Int’l Safety Equipment Assn.
www.safetyequipment.org
(763) 525-1695

Web Site Posts Hydraulics Technology Updates

A new industrial hydraulics Web site provides easy access for technology updates, applications support, expert help, and product information. Also featured are free downloads of literature, training information, and news about the hydraulics industry. This in-depth resource helps first-time visitors get started and find what they need. Featured is a comprehensive hydraulics portfolio ranging from accumulators to valves and related products, to dozens of catalogs, brochures, and interactive materials. Extensive product photos and helpful selection criteria make browsing more interesting and simplifies product selection.

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ESAB Names Four VPs

ESAB Welding & Cutting Products, Florence, S.C., has promoted George Learmonth to vice president of strategic accounts, North America, based in Hanover, Pa. Learmonth previously was director of strategic accounts for ESAB. Greg Stauffer was named vice president of sales support, based in Florence, S.C. Stauffer, with the company for 28 years, previously served as vice president of sales. Jerry Gleisner was appointed vice president of sales, eastern zone, based in Clayton, N.C. Gleisner previously served as zone manager for Sandvik Coromant. David Abe was named vice president of sales, western zone, based in Denver, Colo. Previously, Abe served as executive vice president, sales and marketing, for WIKA Instrument Corp.

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District Sales Manager Named at T. J. Snow

T. J. Snow Co., Chattanooga, Tenn., has appointed Robert J. Hosa a district sales manager, based in Columbus, Ohio. Hosa, with 30 years’ experience in the industry, will be responsible for servicing the company’s resistance welding machine clients throughout the Midwest.

Team Industries Designates Sales VP

Team Industries, Inc., Kaukauna, Wis., a supplier of steel pipe and vessels, has named Michael E. Mincks vice president of sales and estimating. With the company for 15 years, Mincks most recently held the position of estimating manager.

Dulchinos Elected to Robotic Industries Board

John Dulchinos, president and COO of Adept Technology, Inc., Livermore, Calif., a provider of intelligent vision-guided robotics, has been elected to serve a second two-year term as a member of the board of directors of the Robotics Industry Association (RIA). Dulchinos has served in the robotics industry for more than 20 years. The RIA represents about 270 robotics manufacturers, component suppliers, system integrators, end users, research groups, and consulting firms.

Fiber Society Names President

The Fiber Society, Raleigh, N.C., has named Young Chung president for 2008. Chung, with Donaldson Co., Inc., Minneapolis, Minn., for 26 years, has been engaged in nanofiber research, polymer science, and nanofiber chemistry. A Fellow within the Donaldson Corporate Technology group, he is credited with being instrumental in the development of electrospinning nanofiber air filtration and the company’s advanced Ultra-Web® air-filtration technology.

Obituaries

Dinesh Chand Agarwal

Dinesh Chand “D.C.” Agarwal, 64, died April 20. An AWS member since 1991, he served on the A5E Subcommittee on Nickel and Nickel-Alloy Filler Metals. He was a member of ASM International, and American Society of Mechanical Engineers, and chaired numerous technical sessions for the annual conference of the National Association of Corrosion Engineers. He received
Harry F. Prah

Harry Frank Prah, 91, died May 19 in Indianapolis, Ind. An AWS Life Member, affiliated with the Indiana Section, he served as Section chairman, District 14 director, and AWS president (1985–1986). He also served on the D9 Committee on Welding, Brazing, and Soldering of Sheet Metal, and on the Conference and Seminar Committee, and chaired the Technical Council. Prah attended East Technical High School and graduated from Penn College in 1946 with a degree in industrial engineering. He worked as chief inspector at Bryant Heater Co. from 1941 to 1946, and served as plant engineer until 1951. In 1952 he founded Prah Engineering Co. in Indianapolis, where he served as president. He was granted a patent on testing devices, and authored articles on welding applications. Prah was active in Toastmasters International and Boy Scouts of America, where he guided all four of his sons to the rank of Eagle Scout. Prah and his wife, Violet, performed volunteer work at St. Vincent Hospital for many years. He is survived by his wife of 66 years, a sister, four sons, a daughter, nine grandchildren, and five great-grandchildren.

Bevan Braithwaite

Bevan Braithwaite, IIW president (1999–2002) and former chief executive of The Welding Institute (TWI), died April 25 after a long illness. Braithwaite held an engineering degree from Cambridge and a Class 1 Welder qualification. In 1961, he joined TWI as a scientific officer, and friction welding for railways. He was appointed to the TWI executive board in 1966, named TWI director of development in 1981, and became chief executive in 1988. He retired from TWI in 2004. During his retirement, he served as chairman of Bressingham Steam Museum and was active with the Cambridge Museum of Technology. Braithwaite received the Order of the British Empire in 1991, elected a Fellow in the Royal Academy of Engineering in 1999, received the IIW Edström Medal in 2003, and was named an Honorary Fellow of The Welding Institute in 2004.

Russell Stine

Russell “Stiny” Stine, 69, died April 14, in Harrisburg, Pa. An AWS member, he worked in the welding industry for 45 years. He served in the U.S. Army. Active in community affairs, Stine was a life member of the West Hanover Fire Co., Station #38, and a member of the Tall Cedars of Lebanon Upper Shriners Club, Moose Lodge, and the National Rifle Assoc. He was a past president of the Dauphin County Fire and Police Assoc. and the Charlton Paxtonia Lions Club. He was a 32nd Degree Mason and a leader of the Country Americans, a country and western band. Stine is survived by his parents, wife, Nina, four daughters, two sons, three sisters, two brothers, ten grandchildren, and three great-grandchildren.

NEW PRODUCTS

— continued from page 28

Weld Profile Visualization System Uses Phased Array Technology

The company’s scarf monitoring system provides a real-time, online, accurate picture of the inside and outside diameter profiles of scarfed ERW pipes during the manufacturing process. At the center of the system is the ultrasonic phased array transducer that electronically simulates the scanning action required to provide the weld profile information. Next, the resulting information is fed into GE’s UTx digital flaw detection platform. In use, the transducer test head assembly is mounted directly above the weld interface. The mill coolant acts as the ultrasonic coupling medium. Then, the transducer test head uses its phased array elements to monitor the inside and outside diameter of the weld as it is being cut, at a scanning rate of up to 300 profiles/s. Plus, inspection data are displayed in true-to-scale cross-sectional profile at one or multiple monitor screens, and high and low limit alarms provide warning of weld profile deviation.

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• Certified Welding Inspector for the past five years.
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• Auditor certification or certificate of completion for an auditor training course from a nationally or internationally recognized quality organization.
• Participate in/perform one or two monitored AWS Accredited Test Facilities and/or Certified Welding Fabricator audits.
• Attendance and participation in AWS annual auditor seminar after acceptance as an AWS auditor. (This AWS annual seminar is not counted as the nationally recognized auditor training for qualification.)

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AWS Education Services is recruiting a program developer to manage the production of program content for professionals that are currently in the welding profession. Some of the top responsibilities include:

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The susceptibility of Mg alloys to liquid formation and cracking in FSSW and methods to test and explain the susceptibility of Mg and Al alloys are demonstrated

By Y. K. Yang, H. Dong, H. Cao, Y. A. Chang, and S. Kou

ABSTRACT. The use of friction stir spot welding (FSSW) to join Al alloys in automobiles (e.g., by Mazda Motors) is expected to extend to Mg alloys in view of their increasing use to further reduce the vehicle weight. FSSW is considered a solid-state welding process, but liquation (liquid formation) and cracking have been reported recently in Mg alloys in FSSW. In the present study, liquation in Mg alloys was investigated using as-cast AZ91E Mg (~Mg-8.6Al-0.6Zn, a widely used Mg alloy) as an example and 6061-T6 Al (~Al-1Mg-0.6Si, an Al alloy widely welded by FSSW) as a reference for comparison. With the same welding schedule, liquation occurred in AZ91E Mg but not 6061 Al. A simple test with an augmented torque to amplify the difference in the liquation susceptibility between different alloys was demonstrated. It showed no liquation in 6061 Al but severe liquation and cracking in AZ91E Mg, including formation of eutectic liquid films, cracking along liquated grain boundaries, removal of liquated material by the tool, and a mirror-like weld top surface. The microstructural evolution leading to liquation in FSSW was presented. Liquation made the torque fluctuate and fail to show a clear peak as the rotating tool shoulder reached and penetrated the workpiece surface. The heat input, determined from the torque and the axial force, was much less with AZ91E Mg than 6061 Al and thus not why AZ91E Mg liquated more severely. A method to explain the liquation susceptibility was thus proposed. The curves of temperature vs. fraction solid (T-fs) during solidification were calculated. They indicated little liquation-causing constituent in 6061 Al but much more in AZ91E Mg. AM60 Mg, and AZ31 Mg and with a much lower liquidation temperature. Most Mg alloys including these three have Al as the major alloying element, thus providing γ (a Mg-Al compound) to react with α (the Mg-rich phase) and cause liquation by the eutectic reaction $\alpha + \gamma \rightarrow \text{L}$ at a low temperature (~437°C). The effect of heat treating before welding on liquation in FSSW was discussed.

Introduction

Since magnesium (Mg) is about one-third lighter than aluminum (Al), the use of Mg alloys in automobiles is expected to rise rapidly in view of the increasing demand to reduce the vehicle weight in order to improve the fuel efficiency and reduce air pollution. The gas tungsten arc welding (GTAW) process can join Mg alloys satisfactorily, but this process is impractical for the automotive industry. The gas metal arc welding (GMAW) process is much more useful, but severe spatter and porosity often occur in GMAW of Mg alloys. Thus, solid-state welding is an attractive alternative for joining Mg alloys.

Friction stir welding (FSW) is a solid-state welding process invented by The Welding Institute in 1991 (Ref. 1). It has been widely used for welding soft materials such as Al and Mg alloys since then. In FSW the pin at the bottom of a rotating cylindrical tool is plunged into a rigidly held workpiece and traversed along the joint to be welded. Welding is achieved by plastic flow of frictionally heated material from ahead of the pin to behind it. In friction stir spot welding (FSSW), as illustrated in Fig. 1, the rotating tool is also plunged into a rigidly held workpiece but without being traversed along any direction. Welding is achieved by plastic flow of frictionally heated material around the pin. A keyhole is left in the workpiece after the tool is withdrawn at the end of FSW or FSSW. FSSW has recently replaced resistance spot welding in making aluminum rear doors in Mazda RX8 passenger cars.

In FSW the tool travels along the joint and the heat input is distributed along the joint. Liquation, that is, formation of liquid, is unlikely to occur in FSW. Cao and Kou (Ref. 2) found no liquation in FSW of 2219 Al. However, in FSSW the tool remains at one spot, where the heat input dwells. Thus, liquation is much more likely to occur.

Gerlich, Yamamoto, North et al. (Refs. 3–7) have recently conducted temperature measurements in FSSW. They embedded thermocouples in a stationary alloy-steel tool to measure temperatures in a rotating workpiece at the surfaces of the tool shoulder and pin. Temperatures approaching or exceeding the liquation temperature have been measured in Mg alloys including AZ91 Mg extrusions and AM60 Mg sheets prepared by thixomolding (a casting process), wrought AZ31 Mg sheets (Refs. 4, 5), and aerospace Al alloys including 2024 Al and 7075 Al (Ref. 6). Microstructural evidence of liquation was observed in the resultant welds. Thus, liquation can occur in FSSW even though...
FSSW has been considered as a solid-state welding process. However, 6061 Al, a common Al alloy widely welded by FSW and FSSW, was not found to liquef in FSSW (Ref. 7).

Gerlich (Ref. 7) determined the strain rate of the material adjacent to the rotating tool based on EBSD (electron backscattered diffraction). In both the 2024 Al and 7075 Al, the strain rate dropped sharply above a high rotation speed, e.g., 1500 rev/min. This was attributed to tool slippage caused by liquation.

Liquation, if it occurs in FSSW, can interfere with plastic deformation, degrade the weld quality, and even cause cracking. The high plasticity of the material in FSW has been attributed to the very fine grains produced by dynamic recrystallization caused by the intense plastic deformation associated with the movement of material around the pin and friction heating (Refs. 8, 9). FSSW is expected to be similar in this respect. The presence of liquid films can interfere with plastic deformation. More importantly, it can weaken the stir zone and cause it to crack under the torque of the tool. A liquid-penetration-induced (LPI) cracking mechanism of the following sequence was proposed by Yamamoto et al. (Refs. 4, 5) for cracking in AZ91 Mg during FSSW: 1) formation of liquid eutectic films in the periphery of the stir zone, 2) engulfment of liquid eutectic films by the growing stir zone, 3) penetration of the α (Mg) grain boundaries in the stir zone extremity by the liquid eutectic, and 4) crack propagation along the liquated grain boundaries under the torque of the rotating tool. Even without cracking, the eutectic liquid films become brittle after solidification and can thus reduce the ductility and strength of the weld. Kou and coworkers (Refs. 10–16) have shown liquidation-induced cracking in the partially melted zone (PMZ) of Al arc welds and the severe loss of ductility and strength of the PMZ even in the absence of cracking. Various liquation mechanisms in Al arc welds have been discussed by Kou (Ref. 17).

Mg is very similar to Al in many ways, such as low density, low melting point, a soft material weldable by FSSW with an alloy-steel tool, etc. Thus, one may assume that welding schedules good for common Al alloys can automatically be applied to Mg alloys. However, as will be shown in the present study, Mg alloys can be much more susceptible to liquation in FSSW than 6061 Al, and a welding schedule good for 6061 Al may in fact cause liquation in Mg alloys.

The present study investigates the susceptibility of Mg alloys to liquation in FSSW using as-cast AZ91E Mg as an example and 6061 Al as a reference for comparison.

**Experimental Procedure**

**Welds Made without Augmented Torque**

6061 Al was welded in the as-received condition of T6, which stands for solution heat treating and artificial aging (Ref. 18). AZ91E Mg was welded in the as-cast condition. The compositions of the alloys used are listed in Table 1.

For both materials the workpiece was 3.1 mm thick and 64 × 44 mm in area. Spot-on-plate welding was conducted, which is equivalent to lap welding two pieces of 1.5-mm sheets. The tool, prepared from H13-steel, had a shoulder of 10-mm diameter and a threaded pin of 4-mm diameter at the top but tapered down at 10 deg along its 1.8-mm length. This tool will be called the 10-mm-shoulder tool hereafter.

The rotation speed was 1000 or 1200 rev/min, counterclockwise when viewed from above. The plunge rate was about 0.2 mm/s and the dwell time 4 s.

**Welds Made with Augmented Torque**

To amplify the difference in the liquation tendency between different alloys, a liquidation-susceptibility test was adopted in which the torque was augmented by using a relatively large tool for FSSW. This is similar to amplifying solidification cracking in fusion welds in Varestraint testing (Ref. 19), in which an augmented tensile strain is applied during welding to cause the solidifying weld metal to crack. The tool for welding was an H13-steel tool, with a shoulder of 15-mm diameter and a threaded pin of 5.5-mm diameter and 5.1-mm length beyond the bottom of the shoulder. This tool, shown in Fig. 2, will be called the 15-mm-shoulder tool hereafter.

![Image](image.png)

**Fig. 1** Friction stir spot welding (FSSW). A — Plunging; B — stirring; C — withdrawing.

**Table 1** Compositions of Workpiece Materials (wt-%)

<table>
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<tr>
<th></th>
<th>Si</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti</th>
<th>Fe</th>
<th>Al</th>
<th>PMZ</th>
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<td>6061 Al</td>
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<td>0.28</td>
<td>0.08</td>
<td>0.89</td>
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<td>0.01</td>
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<td>balance</td>
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<td>—</td>
<td>1.0</td>
<td>—</td>
<td>3.0</td>
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</tr>
<tr>
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<td>balance</td>
<td>—</td>
<td>—</td>
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<td>6.0</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>AM60 Mg*</td>
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<td>balance</td>
<td>—</td>
<td>balance</td>
<td>—</td>
<td>—</td>
<td>8.60</td>
<td>6.0</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

*Compositions taken from Ref. 7.

To measure the torque and axial force during FSSW, a HAAS TM1 CNC milling machine (5.5 kW or 7.5 hp) equipped with a Kistler Type 9271A dynamometer was used. The dynamometer was cylindrical in shape, and it allowed both the moment acting about its axis and the force parallel to its axis to be measured during FSSW.
The dynamometer allowed torque measurements in the range of –100 to +100 Nm with a 0.02 Ncm threshold and –1.5 pC/Ncm sensitivity for the torque and force measurements in the range of –5 to +20 kN with a 0.02 N threshold and –1.8 pC/N sensitivity for the axial force. A computer-based data-acquisition system was used to collect the data at 250 Hz and display in real time the curves of torque vs. time and axial force vs. time.

Examination of Weld Microstructure

The resultant welds were cut vertically through the meridian plane, mounted, and polished. Welds of 6061 Al were etched with a solution of 0.5 vol-% HF in water. Welds of AZ91E Mg were etched with an acetic-picric solution consisting of 10 mL acetic acid, 4.2 g picric acid, 10 mL water, and 70 mL ethanol in order to reveal more clearly the fine as well as coarse γ-phase in the SEM image of the base metal. In all other cases, AZ91E Mg welds were polished with a water-based polishing suspension during the final polishing stage and thus etched automatically by the water in the suspension during polishing. Both optical microscopy and scanning electron microscopy (SEM) were used, the latter with the secondary electron mode at 15 kV and a 15-mm working distance. The composition of the intermetallic-compound particles in the alloy was determined by energy dispersive spectroscopy (EDS) to help identify them. Photos of the cross sections of the welds were taken with digital cameras.

Results and Discussion

Welds Made without Augmented Torque

These welds were made on the 3.1-mm-thick workpiece with the 10-mm-shoulder tool at 1000- or 1200-rev/min rotation speed, 0.2 mm/s plunge rate, and the 4-s dwell time. Liquation was observed in the case of AZ91E Mg but not 6061 Al, as will be described as follows. Thus, AZ91E Mg is more susceptible to liquation in FSSW than 6061 Al, and a welding schedule good for 6061 Al can cause liquation in AZ91E Mg.

Figure 3A shows the vertical weld cross section of AZ91E Mg made with 1200 rev/min. The optical micrograph in Fig. 3B shows that dark-etching striations are present near the bottom of the keyhole. As revealed by EDS, these striations are richer in Al than the lighter-etching surrounding areas. This suggests that the striations could have been the thin liquid films that partially dissolved (solutionized) in the α matrix. The SEM image in Fig. 3C shows...
shows the SEM image of the base metal far away from the keyhole. Both coarse and fine γ are found in the eutectic between α dendrite arms (Ref. 20). The former grows from the liquid during casting. The latter grows as precipitation from the supersaturated interdendritic α (Ref. 21). EDS showed that the coarse γ contained about 57 wt-% Mg, 37 wt-% Al, and 4.5 wt-% Zn. The weld top surface (the top contact surface of the stir zone in contact with the tool shoulder during FSSW) is shown in Fig. 3E. No evidence of liquation is visible on the weld top surface.

Liquation still occurred even when the rotation speed was reduced to 1000 rev/min. The vertical cross section of the resultant weld is shown in Fig. 4A. Figure 4B and C shows dark-etching striations below and around the bottom of the keyhole. Figure 4D shows a eutectic film in the stir zone near its periphery, in the area marked by the circle in Fig. 4A. Thus, liquation occurred near the stir-zone periphery during FSSW. The weld top surface in Fig. 4E again shows no evidence of liquation.

Welds Made with Augmented Torque

These welds were made on the 9.7-mm 6061 Al and 9.4-mm AZ91E Mg with the 15-mm-shoulder tool at 1000-rev/min rotation speed, 0.15-mm/s plunge rate, and 4-s dwell time. The tool shoulder was increased (from 10-mm diameter) to increase the torque and thus amplify the difference in the liquation tendency between different alloys. The welds, as will be shown as follows, revealed no evidence of liquation in 6061 Al but severe liquation and cracking in AZ91E Mg.

6061 Al

No evidence of liquation was observed. Figure 5 shows the 6061 Al spot weld. The vertical cross section of the weld is shown in Fig. 5A. The workpiece surface before welding is indicated by the two short horizontal broken lines in the photo. The pin length was 5.1 mm, and the pin and shoulder penetrated about 5.9 and 0.8 mm, respectively, below the workpiece surface. The base metal microstructure far away from the keyhole is shown by the SEM image in Fig. 5B. The particles are Fe-rich with 20 to 30 wt-% Fe as shown by EDS. These are the Fe-rich intermetallic compounds commonly present in 6061 Al (Ref. 14). Fe is often present in Al alloys as an impurity and it forms Fe-rich particles because of its very low solubility in Al. The holes along the grain boundary are caused by etching, which was heavy in order to bring out the grain structure in the base metal of 6061 Al.

The microstructure of the stir zone near the weld top surface is shown by the SEM image in Fig. 5C. No signs of liquation are evident. No large Fe-rich particles similar to those in the base metal (Fig. 5B) are present here, suggesting they have been broken up by stirring. The grains in the stir zone are much smaller than those in the base metal, suggesting dynamic recrystallization of new small grains in the stir zone. Figure 5D shows the weld top surface. No evidence of liquation can be seen.

AZ91E Mg

Evidence of severe liquation was observed, including formation of liquid eutectic films, cracking along liquated grain boundaries, removal of liquated material by the tool, and a mirror-like weld top surface. Figure 6 shows the AZ91E Mg spot weld. Figure 6A is the vertical cross section of the weld. The pin and the shoulder penetrated about 5.6 and 0.5 mm, respectively, below the workpiece surface. Figure 6B is an optical micrograph showing cracking across the stir zone and removal of the liquated material from the top of the stir zone. The liquated material stuck to the tool shoulder and was removed by it when the tool was withdrawn at the end of FSSW. The small and large rectangles indicate the locations of Figs. 7 and 8A to be shown subsequently. The weld top surface is mirror-like as shown in Fig. 6C. This is evidence of liquation in the stir zone during FSSW.

Further evidence of liquation and cracking in the AZ91E Mg spot weld is shown by the SEM images in Fig. 8. Figure 8A is a SEM image taken in the lower right corner of the image. A film is enlarged by the inset. The film is normal eutectic (α + γ, that is, composite-like) where it is thick but divorced eutectic (γ plus an α that is connected to the surrounding α matrix) where it is thin. The recrystallized grains in the α dendrites are somewhat visible. In the lower-right corner of Fig. 7, coarse γ particles are visible between α dendrites. In the upper-left half of the same figure, however, only a eutectic consisting of dark α plus thin γ is visible between α dendrites (which tend to be deformed). This eutectic formed as a result of liquation during FSSW.

More evidence of liquation and cracking was observed in the AZ91E Mg spot weld shown in Fig. 8B. AN α dendrite (marked with α) that is deformed but still discernible is visible just to the left of point 2 near the mid-bottom of the micrograph. More dendrites are visible in the lower-right corner of the micrograph.
Figure 8B is an image of the base metal taken at point 1 in Fig. 8A. Microsegregation (that is, coring) of Al and Zn to the interdendritic areas occurs during casting as indicated by the light gray $\alpha$ in the dendrite arms, the dark gray $\alpha$ and white $\gamma$ in the interdendritic areas. Both coarse and fine $\gamma$ are present.

Figure 8C is an image taken at point 2 in Fig. 8A. In the dark interdendritic areas there is no more fine $\gamma$ (Fig. 8B) — only small grains with thin light grain boundaries. Perhaps, there was enough deformation of the interdendritic $\alpha$ to cause recrystallization. When the eutectic temperature $T_E$ was reached, the fine $\gamma$ reacted with $\alpha$ to form liquid eutectic and penetrated the grain boundaries. Upon cooling, the liquid eutectic along the grain boundaries solidified as thin solid eutectic. In fact, as can be seen in the lower-right corner of Fig. 7, similar small grains with thin light grain boundaries and without fine $\gamma$ are present farther away from the stir zone than the long eutectic films. As mentioned previously, Yamamoto et al. (Refs. 4, 5) proposed that the liquid eutectic films in the stir-zone periphery of AZ91 Mg were engulfed by a growing stir zone and that the liquid eutectic penetrated grain boundaries to cause cracking along the grain boundaries under the torque of the rotating tool. However, it is not clear if the liquid eutectic penetrated the grain boundaries here after the liquid eutectic films had formed first and then been engulfed by a growing stir zone.

Figure 8D is an image taken at point 3 in Fig. 8A. The $\alpha$ dendrite arms and the dark interdendritic areas are both severely elongated along the direction of stirring. Because of the friction heat produced by stirring, the peak temperature should be higher here than at point 1, which is already above $T_E$. Some fragments of the coarse $\gamma$ particles might have disappeared after reacting with the interdendritic $\alpha$ and causing further liquation above $T_E$. Upon cooling, the liquid eutectic along the grain boundaries solidified as solid eutectic. It is interesting to note that the small grains in the elongated interdendritic areas are similar to those in the much less deformed interdendritic areas at Point 2 — Fig. 8C.

Figure 8E is an image taken at point 4 in Fig. 8A. It is similar to that at point 3 — Fig. 8D. However, the dark liquated area is now wider, suggesting more liquation here than at point 3. Few $\gamma$ particles are left in the upper-left half of the image. Along the grain boundaries in the interdendritic areas, solidified eutectic is visible ($\alpha + \gamma$ with $\alpha$ connected to the dark interdendritic $\alpha$). This indicates the presence of liquid eutectic along the grain boundaries. A crack runs along the grain boundaries, suggesting cracking occurred along liquated grain boundaries during FSSW.

Figure 8F shows an image taken at point 5 in Fig. 8A. No $\gamma$ particles are visible. The dendrite arms and interdendritic areas have mixed with each other to the extent that they are no longer distinguishable. Solid eutectic is present along the
It seems that if the material is homogeneous in this area, then there probably is no γ present to react with α and cause liquation by the eutectic reaction α + γ → L. If this is true, liquation near the weld surface could have occurred not by the eutectic reaction but by melting of the α phase at the solidus temperature, that is, by α → L. Upon cooling to the eutectic temperature the liquid remaining at the grain boundaries can become liquid eutectic and solidify as solid eutectic.

Microstructural Evolution Leading to Liquation during FSSW

Before proceeding with the microstructural evolution, binary Mg-Al and ternary Mg-Al-Zn phase diagrams are shown first. Figure 9A shows the Mg-rich side of the binary Mg-Al phase diagram (Ref. 22). At the room temperature alloy Mg-8.6Al consists of an α (Mg) matrix and γ (Mg17Al12) particles embedded in it. The eutectic reaction α (Mg) + γ (Mg17Al12) → LE occurs at the eutectic temperature T_E of 437°C, where LE is the liquid eutectic. Figure 9B shows a vertical section (solid lines) of a calculated Mg-Al-Zn ternary phase diagram along which the Al/Zn ratio equals 8.60/0.65 (in wt-%). The vertical section, which is also called an isopleth, includes AZ91E Mg (Mg-8.60Al-0.65Zn if its 0.24 wt-% Mn is ignored as can be seen in Table 1). A calculated binary Mg-Al phase diagram (broken lines) is included for comparison. These two phase diagrams were calculated using the thermodynamic computer code Pandat (Ref. 23) and the database of Mg alloys (Ref. 24). The difference between the two calculated phase diagrams is very small. As shown in Table 1, AZ31 Mg is Mg-3.0Al. AZ91E Mg is approximately Mg-8.6Al if Zn (0.65%) and Mn (0.24%) are ignored. Likewise, AM60 Mg is approximately Mg-6.0Al if Mn (0.5%) is ignored. Thus, the binary Mg-Al phase diagram can be used as an approximation for the vertical section of a ternary Mg-Al-X phase diagram if the content of solute X is small.

The microstructural evolution leading to constitutional liquation in Mg alloys during FSSW is shown in Fig. 10, based on the weld microstructure in AZ91E Mg shown in Fig. 8. Figure 10A is a schematic sketch of the vertical cross section of a weld of alloy C0 made by FSSW. Alloy C0 has an abundant γ and a relatively low T_E as most Mg alloys. Figure 10B shows a phase diagram that includes the alloy. It is either a binary Mg-Al phase diagram (Fig. 9A) if the alloy is close to a binary Mg-Al alloy, or a vertical section of a ternary Mg-Al-X phase diagram if the alloy is close to a ternary Mg-Al-X alloy (e.g., Fig. 9B).

The microstructural evolution at a location (point P) heated up to a peak temperature of T_p during FSSW is illustrated in Fig. 10C. At the room temperature T_R alloy C0 in its as-cast condition consists of an α matrix and γ particles embedded in it.
The $\alpha$ phase is shown in two different colors — light gray for the dendrite arms and dark gray for the interdendritic area. During casting solute microsegregation causes the liquid to solidify first as $\alpha$ lower in Al ($< C_0$) in the dendrite arms and finally as $\alpha$ higher in Al (up to $C_{SM}$) and as $\gamma$ in the interdendritic areas (similar to Fig. 8B).

Because of the high heating rate during FSSW, $\gamma$ does not have enough time to dissolve in the $\alpha$ phase upon heating to $T_3$ even though they should do so under the equilibrium (very slow heating) condition according to the phase diagram — Fig. 10B. This is because the solid-state diffusion required for $\gamma$ dissolution to occur is very slow in view of the very small solid diffusion coefficient (on the order of $1 \times 10^{-8}$ cm$^2$/s). The $\alpha$ phase has been deformed by stirring and perhaps some small grains have formed by dynamic recrystallization.

Upon further heating to the eutectic temperature $T_E$, the remaining $\gamma$ particles start to react with the surrounding $\alpha$ matrix and cause liquation by the eutectic reaction $\alpha + \gamma \rightarrow L_E$, where $L_E$ is the liquid eutectic — Fig. 10C. This liquation mechanism is the so-called “constitutional liquation” originally observed in fusion welds by Pepe and Savage (Refs. 25, 26). It requires a high heating rate, which usually exists in welding, in order to have $\gamma$ remain at $T_E$ to react with $\alpha$ and cause liquation. The liquid eutectic penetrates the grain boundaries and solidifies as solid eutectic along the grain boundaries upon cooling.

The microstructural evolution at a location (point Q) heated up to $T_3$ (> $T_E$) is illustrated in Fig. 10D. Here, $\alpha$ is severely elongated in the direction of stirring, $\gamma$ breaks up and more liquation occurs. Since bonding between grains can be severely weakened by the presence of liquid, cracking can occur along liquated grain boundaries under the shear force caused by stirring — Fig. 8E. Upon cooling, the liquid eutectic $L_E$ forms solid eutectic $S_E$ along the grain boundaries (similar to Fig. 8D, E).

The microstructural evolution at a location (point R) further up in the stir zone where the material is well mixed is illustrated in Fig. 10E. Here, the peak temperature during FSSW is $T_4$ (> $T_3$) to $T_E$. The $\alpha$ dendrites and the interdendritic areas are well mixed and indistinguishable. Upon cooling, the liquid eutectic $L_E$ forms solid eutectic $S_E$ along the grain boundaries (similar to Fig. 8F).

**Torque and Axial Force**

For a given alloy the tendency to liquate during welding increases with the heat input (Ref. 17). Thus, knowing the heat input in FSSW can help determine whether the difference in the extent of liquation between different alloys is caused by the difference in the heat input or the real susceptibility to liquation. The heat input during FSSW of a given alloy can be affected significantly by its mechanical properties such as the strength. Since the temperature and hence strength vary significantly within the stir zone, it is hard to discuss the heat input based on the strength. An easier way is to analyze the torque and the axial force during FSSW.

Figure 11 shows that both the torque $T_M$ of the rotating tool and the axial force $F_z$ vary with time $t$ and from alloy to alloy. The penetration period lasts for about 42 s and is followed by a 4-s holding period before tool withdrawal. From the torque curve of 6061 Al (Fig. 11A), it can be seen that the rotating tool shoulder reaches the workpiece surface at about 33.5 s. So, the average plunge rate of the 5.1-mm-long pin is about 0.15 mm/s (5.1 mm ÷ 33.5 s), which is identical to the 0.15 mm/s plunge rate used in the experiment. The shoulder plunges for about 8.5 s (42 – 33.5 s). As mentioned previously, the shoulder penetrated only about 0.8 mm below the workpiece surface instead of 1.3 mm (8.5 s × 0.15 mm/s). This difference probably can be accounted for by the very slight workpiece distortion (the resultant workpiece bent downward slightly in the area under the keyhole) and the flexibility in the milling machine system in view of the much (about 7 times) larger cross-sectional area of the shoulder than the pin.

For 6061 Al, a peak torque of about 23 Nm starts to show up at 33.5 s when the rotating tool shoulder reaches the workpiece surface. During the last 4-s holding period, the torque decreases significantly. Initially ($t = 0$ s), the torque rises quickly and then more slowly as the adjacent workpiece material is heated up and softened. This results in the torque rising again but with fluctuation. The fluctuation is not caused by liquation because of the absence of liquation — Fig. 5. This is likely to be caused by the material expelled by the tool but entrapped between the rotating shoulder and the stationary workpiece surface, which tended to switch back and forth between rotating and stopping.

For AZ91E Mg (Fig. 11B) the torque curve is far below that of 6061 Al, with a maximum torque of only about 10 Nm. No clear peak starts to show up in the torque curve when the rotating tool shoulder reaches the workpiece surface at 33.5 s. The absence of a clear peak torque and the fluctuation of the torque are likely to be caused by liquation. It is likely that when liquid forms, the torque and hence temperature tend to decrease. When the liquid cools and solidifies, the torque and hence temperature increase, and liquid forms again to repeat the cycle.

As shown in Fig. 11, both alloys show two peaks in the curve of axial force $F_z$ vs. time $t$. The axial force rises quickly initially but decreases as the adjacent workpiece material is heated up and softened. This results in a first peak of about 8 kN in 6061 Al and 7 kN in AZ91E Mg. The axial force rises...
quickly again as the tool shoulder approaches the workpiece surface. This results in a second peak of about 10 kN in 6061 Al and 15 kN in AZ91E Mg. For 6061 Al, the much lower second peak might be related to its known excellent extrudability. The axial force fluctuated during the same period of time when the torque fluctuated.

**Heat Input during FSSW**

Let \( M_z \) be the torque (in Nm), \( \Omega \) the rotation speed (in rev/min), and \( t \) time (in s).

Then the contribution of rotation to the heat input \( Q_\Omega \) (in Joules) is as follows (Ref. 27):

\[
Q_\Omega = \int_0^t M_z \left( \frac{2\pi \Omega}{60} \right) dt
\]

Likewise, let \( F_z \) be the axial force (in N) and \( v_z \) the plunge rate (in m/s). Then, the contribution of tool plunge to the heat input \( Q_F \) (in Joules) is as follows (Ref. 28):

\[
Q_F = \int_0^t F_z v_z dt
\]

Both the rotation speed \( \Omega \) and the plunge rate \( v_z \) are often held constant during FSSW. For both materials in the present study, \( \Omega = 1000 \text{ rev/min} \) and \( v_z = 1.5 \times 10^{-4} \text{ m/s} \). Thus, for constant \( \Omega \) and \( v_z \), the total heat input \( Q \) due to both tool rotation and plunge in FSSW is as follows:

\[
Q = Q_\Omega + Q_F = \int_0^t M_z \left( \frac{2\pi \Omega}{60} \right) dt + \int_0^t F_z v_z dt
\]

The first integral on the right-hand side of Equation 3 is the area under the \( M_z \times t \) curve. Likewise, the second integral is the area under the \( F_z \times t \) curve. As shown in Table 2, the heat input \( Q_\Omega \) due to tool rotation is 67.5 kJ with 6061 Al and 32.3 kJ with AZ91 Mg. The heat input \( Q_F \) due to tool plunge is 35 J with 6061 Al and 51 J with AZ91E Mg. Thus, in FSSW \( Q_\Omega \) is much less than \( Q_F \). The total heat input \( Q \) is 67.5 kJ with 6061 Al and 32.3 kJ with AZ91E Mg, this is consistent with the much lower heat input with AM50 than with 6061 Al observed by Su et al. (Ref. 28).

Thus, the much higher liquation susceptibility of AZ91E Mg in FSSW than 6061 Al cannot be explained by a higher heat input with AZ91E Mg.

**Explanation for Liquation Susceptibility in FSSW**

A method to explain the liquation susceptibility of an alloy in FSSW is proposed below.

**T-fS Curves and Phase Diagrams**

The curve of temperature vs. fraction solid (T-fS) during solidification shows the eutectic temperature and the amount of the eutectic in an as-cast alloy. The phase diagram also helps identify the liquation-causing constituent in the alloy, for instance, an intermetallic compound in a wrought alloy or a eutectic in an as-cast alloy. In any case, the more abundant the liquation-causing constituent and the lower the liquation temperature, the greater the liquation susceptibility is.

Figure 12 shows the T-fS curves of AZ31 Mg, AM60 Mg, and AZ91E Mg during solidification. The compositions of these Mg alloys are shown in Table 1. For comparison, the T-fS curve of 6061 Al is also included as a reference. They were calculated based on the Scheil model using Pandat (Ref. 23) and the solidification databases of Al alloys (Ref. 29) and Mg alloys (Ref. 24). The T-fS curve for AZ91E Mg has also been calculated by Ohno et al. (Ref. 21) using Pandat and the Mg-alloy database (Ref. 24).
Figure 13 shows the solidus projections of the ternary phase diagrams of Al-Mg-Si (Ref. 30) and (Mg+0.2Mn)-Al-Zn (Ref. 21) on the composition (horizontal) plane. The solidus temperature $T_S$ and the line of solid-solubility limit are shown as a function of composition.

6061 Al

As shown by its $T_f-S$ curve in Fig. 12, 6061 Al does not have much liquation-causing constituent even in the as-cast condition. Even less or none is left after the T6 heat treating. As shown in Table 1, the composition of the 6061 Al used is Al-0.89 Mg-0.62Si-0.52Fe-0.28Cu 0.19Cr 0.08Mn. Fe can be neglected because Fe-rich particles (Fig. 5B) do not cause liquation in 6061 Al (Ref. 14).

AZ91E Mg

According to its $T_f-S$ curve shown in Fig. 12, AZ91E Mg reaches the eutectic reaction $L \rightarrow \alpha + \gamma$ at 432°C and a fraction solid of 0.85, the effect of the low Mn content in this alloy on the curve being negligible. Thus, the AZ91E Mg has a rather high fraction of eutectic of about 15% and a very low eutectic temperature of 432°C, which is 109°C lower than the lowest eutectic temperature of 6061 Al 541°C. This clearly suggests that AZ91E Mg should have a significantly greater tendency to liquate than 6061 Al. The evidence of liquation, cracking, removal of liquated material by the tool, and a mirror-like weld surface shown in Figs. 6 and 7 all confirm the liquation susceptibility of AZ91E Mg.

Other Mg Alloys

Al is the most common alloying element in Mg alloys, and most Mg alloys contain Al as a major alloying element, such as AZ91 Mg, AM60 Mg, and AZ31 Mg, where the first alphabet “A” stands for Al and the first digit for its content (in wt-% and rounded to the closest whole number). As already shown by the Mg-Al phase diagram in Fig. 8A, the eutectic reaction $L \rightarrow \alpha (Mg) + \gamma (Mg_17Al_{12})$ occurs at the eutectic temperature 437°C. Consequently, Mg alloys containing Al tend to liquate at a very low temperature near or even below 437°C.

Figure 12 shows that the Mg alloys have a much lower eutectic temperature and much more eutectic than 6061 Al. The eutectic temperature and the amount of eutectic are 541°C and 1% for 6061 Al, 432°C and 15% for AZ91E Mg, 436°C and 8% for AM60 Mg, and 413°C and 4% for AZ31 Mg.

Thus, it is not surprising that Yamamoto et al. (Ref. 4) observed liquation.

Table 2 — Heat Inputs in FSSW

<table>
<thead>
<tr>
<th></th>
<th>Heat Input from Rotation $Q_o$ (J)</th>
<th>Heat Input from Plunging $Q_p$ (J)</th>
<th>Total Heat Input $Q$ (J)</th>
<th>$\int M_o$ dt (Nm s)</th>
<th>$\int F_z$ dt (kN s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6061 Al</td>
<td>67512</td>
<td>35</td>
<td>67547</td>
<td>644.7</td>
<td>232.9</td>
</tr>
<tr>
<td>AZ91E Mg</td>
<td>32285</td>
<td>51</td>
<td>32336</td>
<td>308.3</td>
<td>338.3</td>
</tr>
</tbody>
</table>

Fig. 11 — Tool torque and axial force measured during FSSW. A — 6061 Al; B — AZ91E Mg. Area under each curve proportional to heat input generated by either rotation $(M_Z)$ or plunge $(F_Z)$ of tool. 15-mm-diameter shoulder, 1000-rev/min rotation speed.

Fig. 12 — $T_f$ curves during solidification explaining why Mg alloys are much more liquation susceptible than 6061 Al. Eutectic temperatures and contents: 541°C and 1% for 6061 Al, 432°C and 15% for AZ91E Mg, 436°C and 8% for AM60 Mg, and 413°C and 4% for AZ31 Mg. Curves calculated based on Scheil model of multicomponent alloys using Pandat of CompuTherm LLC (Refs. 21, 23).
Effect of Heat Treating on Liquation Susceptibility

In the binary phase diagram in Fig. 9A, the vertical projection of the solidus line on the horizontal (composition) axis is a line segment. The projection of the solidus plane of a ternary phase diagram on its horizontal (composition) plane, called the solidus projection, is indicated by a shaded area like one of those in Fig. 13. The broken lines within each shaded area indicate how the solidus temperature varies with the composition.

For 6061 Al, as shown by the solidus projection in Fig. 13A, constitutional liquation can occur if liquation-causing constituents are present. Some 6061 Al alloy contains Si-rich particles (Ref. 14), and liquation can occur by the eutectic reaction \( \alpha + \text{Si} \rightarrow L \) at 577°C or by the eutectic reaction \( \alpha + \text{MgSi} + \text{Si} \rightarrow L \) at 555°C (Ref. 31). Based on the approximate composition of ternary Al-0.9Mg-0.6Si alloy as an approximation and the ternary Al-Mg-Si solidus projection shown in Fig. 13A, it is possible to dissolve all liquation-inducing constituents completely by heat treating at a temperature below the solidus temperature 595°C. Such a 6061 Al can liqueate by melting when the solidus temperature 595°C is reached, which is rather high and unlikely to reach in FSSW.

As already shown, constitutional liquation occurs in AZ91E Mg in FSSW. Based on the approximate composition of Mg-8.6Al-0.65Zn-0.2Mn and the ternary (Mg-0.2Mn)-Al-Zn solidus projection shown in Fig. 13B, it is possible to dissolve \( \gamma \) completely by heat treating at a temperature near but below the solidus temperature 475°C. This can raise the liquation temperature from the eutectic temperature 432°C to the solidus temperature 475°C. However, this is still significantly (72°C) lower than the liquation temperature of 6061 Al (541°C), thus suggesting that a heat treated AZ91E Mg can still be more susceptible to liquation. Unfortunately, many Mg alloys are used in the as-cast condition, thus providing \( \gamma \) (a Mg_2Al_3 compound containing other alloying elements, e.g., Zn) to react with \( \alpha \) (Mg) and cause liquation upon heating by the eutectic reaction \( \alpha + \gamma \rightarrow L \) at a low eutectic temperature \( T_E \) (e.g., ≤ 437°C).

2) The susceptibility of these Mg alloys to liquation in FSSW is promoted by 1) a liquation-causing constituent and a low \( T_E \) and 2) the heat input dwelling at one spot (instead of spreading along the joint path as in FSW).

3) Although Mg is very similar to Al in being light, soft and weldable by FSSW with an alloy-steel tool, a welding schedule good for an Al alloy widely welded by FSSW such as 6061 Al may, in fact, cause liquation in Mg alloys. It is essential to keep the heat input as low as possible and check the weld on liquation and cracking.

4) A liquation-susceptibility test with an augmented torque in FSSW to amplify the difference in liquation between different alloys has been demonstrated, providing not only a simple reliable method for susceptibility testing but also a tool for more clearly examining and understanding liquation.

5) The \( M_2\gamma \) (torque vs. time) curve can be used to diagnose liquation in real time during FSSW. A curve fluctuating and lacking a clear peak as the rotating tool shoulder reaches and penetrates the workpiece surface indicates likely liquation.

6) A method for explaining the liquation susceptibility in FSSW has been demonstrated, with the \( T_F \) (temperature vs. fraction solid) curve to indicate \( T_E \) and estimate the eutectic content, with the phase diagram to identify the liquation-causing constituent and determine the effect of heat treating, and with the \( M_2\gamma \) curve to check the heat input.

7) Formation of liquid eutectic films, cracking along liquated grain boundaries, removal of liquated material by the tool, and a mirror-like weld top surface have been observed in AZ91E Mg but not in 6061 Al, thus confirming the liquation susceptibility of AZ91E Mg in FSSW (indicated by the liquation-susceptibility test) regardless of its much lower heat input (indicated by the torque measurement).

8) The microstructural evolution leading to liquation in FSSW has been presented for alloys with a liquation-causing constituent \( \gamma \) and a low \( T_E \) like most Mg alloys.

9) When comparing different alloys in the liquation susceptibility in FSSW, it is desirable to check the heat input in welding each alloy, which can be determined from the \( M_2\gamma \) curve, because the extent of liquation in a given alloy increases with increasing heat input.
10) Heat treating as-cast Mg alloys before welding may reduce liquation in FSSW by reducing γ, but a more effective way is to keep the heat input as low as possible if there is still enough stirring to achieve sufficient bonding.

Acknowledgments

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References

Experimental and Numerical Analysis of the Friction Welding Process for the 4340 Steel and Mild Steel Combinations

A model was developed that can be used as an industrial tool to predict evolution of temperature, stress, strain, and final geometry of the welded parts

BY S. A. A. AKBARI MOUSAVI AND A. RAHBAR KELISHAMI

ABSTRACT. During friction welding, temperature, stress, strain, and their variations govern welding parameters, and knowledge of them helps determine optimum parameters and ways to improve the design and manufacture of welding machines. The finite element method was used for the coupled thermomechanical problem, and the Johnson-Cook equation was used to define material properties. The variations in temperature, deformation, stress, strain, and strain rate during continuous welding were systematically investigated and analyzed. The calculated results of temperature distribution were in good agreement with the infrared detected ones. The numerically calculated results for the shape of the welded joint also showed an excellent fit with the experimental observations. The effects of initial and final pressure on internal parameters are discussed. Moreover, the metallographical examinations, hardness, and tensile tests of the samples were carried out. In addition, in this study, the operational parameters of the friction welding process are related to the physical parameters of the process.

Introduction

Friction welding is a complicated metallurgical process, accompanied by a series of physical phenomena: frictional heat generation, plastic deformation, cooling of high-temperature metal, and solid-state phase variation. In the continuous-drive friction welding processes, the thermomechanical behavior at the interface is obviously critical to the quality of the welded joint. Friction welding is a process in which the heat for welding is produced by direct conversion of mechanical energy to thermal energy at the interface of the workpieces. In order to model the friction welding process, a combination of thermal effects and plastic deformation is needed.

The friction welding process is a solid-state joining process that produces a weld under the compressive force contact of one rotating and one stationary work-piece. The heat is generated at the weld interface because of the continuous rubbing of contact surfaces, which, in turn, causes a temperature rise and subsequent softening of material. Eventually, the material at the interface starts to flow plastically and forms an upset. When a certain amount of upsetting has occurred, the rotation stops and the compressive force is maintained or slightly increased to consolidate the weld. Friction time, friction pressure, forging time, upset time, forging pressure, and rotation speed are the most important operational parameters in the friction welding process.

Few attempts have been carried out in the literature to simulate the friction welding process. In these studies, only one or two of the operational parameters were discussed. Most of the simulations were performed for the stir and inertia friction welding processes. Only a few efforts were reported in the literature for the continuous friction welding process. Vairis et al. (Ref. 1) simulated linear friction welding of titanium bars. He predicted the temperature rise in the initial phase of the process. Sluzalec (Ref. 2) used the finite element method (FEM) to determine the stress and strain distributions during the welding process. Fu et al. (Ref. 3) simulated deformation and transient temperature during the process by the finite element method. Alvise et al. (Ref. 4) simulated the two-dimensional inertia friction welding process for two dissimilar materials, though the names of the materials modeled were not reported. Recently, Sahin (Ref. 5) introduced a friction subroutine in his Visual Basic program to model the shape of the upset in the continuous friction welding process.

In this study, friction welding experiments were carried out for 4340 and mild steel combinations. The various materials were used to validate the simulation results. All of the experiments performed were modeled using the ABAQUS code and under similar conditions. The physical parameters such as temperature, stress, strain, and strain rate fields for a friction welded joint of a few materials in bar form were calculated under given boundary conditions. Variable thermal and mechanical properties of the welded material were taken into account. The simulation results were validated against the experiments. An infrared detector was used to measure the temperature at the contact surface of the weldment. The infrared detector results are compared with the simulated values. The observed shape of the welded joint is also compared with the simulated one. In all the tension tests carried out, the samples were broken from their base metals and not the welds. The metallographical examinations of the specimens were also performed. Moreover, in this study, the operational parameters of the friction welding process are related to the physical parameters of the process.

Experimental Samples

Experiments were carried out to friction weld the samples with 20-mm diame-
WELDING RESEARCH

Materials

In this investigation, Grade 4340 steel and mild steel were used. The chemical compositional ranges, and mechanical and physical properties for the materials used in this study are given in Tables 2–4, respectively.

The typical final shape of mild steel to mild steel bars and 4340 steel to mild steel bars obtained from the experiments is shown in Fig. 1A and B, respectively. Comprehensive information about the numerical and experimental phases of other materials can be found in Rahbar (Ref. 6).

Modeling

In this investigation, the continuous friction welding process of Grade 4340 steel and mild steel was numerically simulated by the ABAQUS 6.4-11 Pro commercial software code (Ref. 7). The objective of the study was to consider the variations of temperature, deformation, stress, strain, and strain rate during the process. Moreover, in this study, the operational parameters of the friction welding process are related to the physical parameters of the process.

Johnson-Cook Constitutive Equation

In the friction welding process, continuous rubbing of contact surfaces generates the heat at the weld interface. The temperature of the material increases with heat and therefore subsequent softening of the material occurs. The material at the interface starts to flow plastically and forms an upset collar. Therefore, the type of equation that can be used to describe the material behavior during the process must include the effect of temperature as well as strain and strain rate. Therefore, the Johnson-Cook equation (Ref. 8) is used in which the von Mises yield stress is defined as a function of strain, strain rate,

---

Table 1 — Friction Welding Parameters of the Various Experiments Performed

<table>
<thead>
<tr>
<th>Materials</th>
<th>Initial Pressure (MPa)</th>
<th>Final Pressure (MPa)</th>
<th>Friction Time (s)</th>
<th>Rotation Speed (rev/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4340 Steel–4340 Steel</td>
<td>80</td>
<td>100</td>
<td>7</td>
<td>3000</td>
</tr>
<tr>
<td>Mild Steel–Mild Steel</td>
<td>20</td>
<td>30</td>
<td>6</td>
<td>3000</td>
</tr>
<tr>
<td>4340 Steel–Mild Steel</td>
<td>50</td>
<td>75</td>
<td>6</td>
<td>3000</td>
</tr>
</tbody>
</table>

Table 2 — Composition Ranges of the Materials Used in This Study

<table>
<thead>
<tr>
<th>Grade</th>
<th>C (min.)</th>
<th>Mn (min.)</th>
<th>Si (min.)</th>
<th>P (min.)</th>
<th>S (min.)</th>
<th>Cr (min.)</th>
<th>Mo (min.)</th>
<th>Ni (min.)</th>
<th>C (max.)</th>
<th>Mn (max.)</th>
<th>Si (max.)</th>
<th>P (max.)</th>
<th>S (max.)</th>
<th>Cr (max.)</th>
<th>Mo (max.)</th>
<th>Ni (max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4340 Steel</td>
<td>0.38</td>
<td>0.6</td>
<td>0.15</td>
<td>—</td>
<td>—</td>
<td>0.7</td>
<td>0.2</td>
<td>1.65</td>
<td>0.43</td>
<td>0.8</td>
<td>0.30</td>
<td>0.035</td>
<td>0.04</td>
<td>0.9</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Mild Steel</td>
<td>0.03</td>
<td>0.2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.25</td>
<td>16</td>
<td>0.5</td>
<td>0.05</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 3 — Mechanical Properties of the Materials Used in This Study

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile Strength (MPa)</th>
<th>Yield Strength 0.2% Proof (MPa)</th>
<th>Elongation (% in 50 mm) min.</th>
<th>Rockwell C (HRC) max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4340 Steel</td>
<td>744.6</td>
<td>473.2</td>
<td>22</td>
<td>39</td>
</tr>
<tr>
<td>Mild Steel</td>
<td>420</td>
<td>350</td>
<td>15</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 4 — Physical Properties of the Materials Used in This Study

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density (kg/m³)</th>
<th>Elastic Modulus (GPa)</th>
<th>Mean Coefficient of Thermal Expansion (μm/m°C)</th>
<th>Thermal Conductivity (W/m.K) at 100°C</th>
<th>Specific Heat (J/kg.K) at 500°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>4340 Steel</td>
<td>7700–8300</td>
<td>190–210</td>
<td>17.2</td>
<td>16.2</td>
<td>500</td>
</tr>
<tr>
<td>Mild Steel</td>
<td>7800–8000</td>
<td>200</td>
<td>9.5–12.6</td>
<td>44</td>
<td>470</td>
</tr>
</tbody>
</table>

Fig. 1 — The final shape of the following friction welds: A — Mild steel to mild steel; B — 4340 steel to mild steel.
and temperature, i.e.,

$$\sigma = \left( A + \frac{B}{\varepsilon^p} \right) \times \left( 1 + c \cdot \ln \varepsilon^p \right) \times \left( 1 - T^m \right)$$

(1)

where \( \varepsilon \) is the equivalent plastic strain, \( \varepsilon^p \) is the plastic strain rate, \( T^o \) is the homologous temperature

$$\frac{T - T_{room}}{T_{melt} - T_{room}},$$

and \( T \) is the absolute temperature. A, B, n, c, and m are five constants. The expression in the first set of brackets gives the stress as a function of strain for \( \varepsilon^p = 1 \) and \( T^o = 0 \).

The Johnson-Cook parameters for the materials used in this study are tabulated in Table 5.

### The Finite Element Modeling of the Friction Welding Process

In this analysis, the eight-node element was used. The modeling was performed 3D with reduced integration points and coupled temperature-displacement equations were employed. The C3D8RT element type was used. A proper contact algorithm was employed in the model. The general contact algorithm is used in modeling the friction welding process due to the following reasons:

- During the friction welding process, more than two surfaces can take part in contact.
- The edge of the materials must be included during the contact procedure.

In addition, an algorithm was written and coded into the software to express the contact definition of the process. Two-step modeling was used in order to suitably express the process. In the first step, rotating and transition speeds were applied to the left bar and when a certain amount of upsetting had occurred, the second step, the rotation stopped and the compressive force was maintained or slightly increased to consolidate the weld. The boundary condition is defined so that the materials positioned in the right-hand side of the paper are fixed, and the materials suited in the left-hand side of the paper are rotating. According to this, the centerline nodes could only move in the “z” axis and not in “x” or “y” axis. The initial and final pressures are applied to the fixed bar. The initial pressure is applied during the welding time in which its values are increased to the final pressure during the braking time while the rotating speed decreases to zero. The adaptive mesh type was used to adjust with the grain refinement during the contact deformation process. Thermal effects are assumed to be adiabatic.

### Table 5 — The Johnson-Cook Parameters for the Materials Used in This Study (Ref. 7)

<table>
<thead>
<tr>
<th>Material</th>
<th>A (MPa)</th>
<th>B (MPa)</th>
<th>n</th>
<th>C</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>310</td>
<td>350</td>
<td>0.3</td>
<td>0.02</td>
<td>0.5</td>
</tr>
<tr>
<td>4340 Steel</td>
<td>792</td>
<td>510</td>
<td>0.26</td>
<td>0.014</td>
<td>1.03</td>
</tr>
</tbody>
</table>
Results of the ABAQUS Analyses and Experiments

Figure 2 shows the initial configuration of the process. The final configuration of the friction welding of 4340 steel bar to mild steel bar is shown in Fig. 3. The left-hand side of the model in Fig. 3 is the 4340 steel bar. The final shape of the mild steel bar to mild steel bar is depicted in Fig. 4. Comparing Figs. 1 and 3 shows that simulation is relatively successful in modeling the out shape of the weld. The thin edge of the upset produced in experimental results could not be achieved due to the limitation of element size and type and avoidance of more complexity.

Validation of the Simulation Results

The sizes of upsetting occurring during the friction welding process were compared with the corresponding simulation results. The results are tabulated in Table 6. Validation of temperature results are described in the Hardness Distributions section of this paper.

To analyze the simulation results, a typical “centerline” path similar to what is shown in Fig. 5 is chosen. The path has 150 mm length and includes the weld zone, the heat-affected zones (HAZ), and parts of both base metals. The path starts at 50 mm from the left bar end to 50 mm from the right bar end. It covers all the changes that might occur during the friction welding process.

Microstructures

The metallographic images of the mild steel to mild steel samples before and after welding are shown in Fig. 6A-C. Figure 6B, C shows the fine grain size structure produced at the HAZ and the weld zones, respectively. After cooling and applying the subsequent pressure, the process of recrystallization and growth takes place that results in a fine grain structure — Fig. 6C. The fusion zone has finer grain than the HAZ. Typical temperature profile obtained from the simulation is shown in Fig. 6D. Figure 6D shows a very high temperature is produced at the collision zone. In addition, it will be shown later in the section titled Plastic Strain Distributions that the very high plastic strain is produced at the collision zone. High-temperature and plastic strain with fast cooling results in a fine grain structure at the contact zone. According to the Hall-Petch equation, the material strength depends on the grain size, and smaller grains produce the higher strengths (strength test results are described in the next section).

Similar trends are seen in friction welding of other samples. Figure 7A, B shows the metallographic images of the 4340 steel to mild steel samples before and after welding, respectively.

The Tensile Tests

Experiments were also conducted to measure the weld strength of the samples. Figure 8A shows the tensile test of mild steel before the weld, and Fig. 8B depicts the tensile strength of the weld after the friction welding process. The two figures are similar showing the rupture occurs in the mild steel base bars and not at the weld zone.

Hardness Distributions

The study was also conducted to find the hardness distributions across the joints. Figure 9 shows the typical hardness distributions (in Vickers) for the friction welded joints of 4340 steel-mild steel. Maximum hardness is obtained at the fusion zones (which have a finer grain size). The hardness is decreased in the HAZ due to temperature softening and coarser grain size structure produced (see typical temperature profile in Fig. 6D and microstructure in Fig. 6B). In the experiments and the simulations, the bars were fixed at the right-hand side and rotating at the left-hand side of the figure. This produces some rigidity at the bar ends and causes the increase of hardness at a distance far away from the weld centerline. The increase in hardness away from the joints, which is due to fixing the bars during the test, is shown in Fig. 9.

The Temperature Distributions

Friction causes the increase in temperature at the interface. The highest temperature is obtained at the weld centerline and the temperature decreases with distance away from the weld centerline. Figure 10A shows the temperature distribu-

Table 6 — Comparison of Upsetting Thickness between Simulations and Experiments

<table>
<thead>
<tr>
<th>Materials</th>
<th>Size of Upsetting (Simulation) (mm)</th>
<th>Size of Upsetting (Experiments) (mm)</th>
<th>Comparison (% Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel-Mild Steel</td>
<td>1.9</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>4340 Steel-4340 Steel</td>
<td>1.8</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>4340 Steel-mild Steel</td>
<td>2.3</td>
<td>2.2</td>
<td>4.5</td>
</tr>
</tbody>
</table>
tions for friction welding of 4340 steel to mild steel material bars, and Fig. 10B shows profiles for friction welding of mild steel to mild steel bars. The graphs are drawn based on the normalized temperature. The normalized temperature is the ratio of actual temperature to the melting point temperature in °C. The data on the figures show the ratio of actual temperature to the melting temperature for some critical points. The figures clearly show that the welding zones consist of two heat-affected zones and a center zone. Higher temperature is obtained for the friction welding of 4340 steel to mild steel materials. The heat-affected zone peak temperature is found to be lower in the right-hand sides of Fig. 10A and B than it is in the left-hand side of Fig. 10A and B. The difference is attributed to positioning the fixed bar to the right-hand side of the figures and suit the rotating bar in the left-

Fig. 7 — Metallographic images of the interface of 4340 steel to mild steel: A — The initial 4340 steel structure before welding; B — the microstructure achieved after welding in the fusion zone of 4340 steel-mild steel friction weld sample (initial mild steel structure is shown in Fig. 6A).

Fig. 8 — Stress-strain graphs: A — The mild steel specimen; B — the mild steel to mild steel weld.

hand sides of the figures and the initial and final pressures are applied to the fixed bars. The maximum temperatures measured by the infrared detector for the 430-mild steel and mild steel-mild steel combinations were 1425° and 1480°C, respectively. The corresponding simulation results predicted were 1440° and 1520°C, respectively.

The Plastic Strain Distributions

The transient temperature produced in the friction zone causes the variations of all the physical parameters during the friction welding process. The plastic strain distributions are similar in shape to the temperature distributions. Figure 11A shows the plastic strain distributions for friction welding of 4340 steel to mild steel materials, and Fig. 11B depicts profiles for the friction welding of mild steel to mild steel bars, respectively. The peak plastic strain is obtained at the centerline. The figures show that the plastic strain decreases with distance from the centerline. In the heat-affected zone, the plastic strain increases slightly due to the increase of temperature. The temperature decreases further at distances away from the heat-affected zones.

The Von Mises Stress Distributions

Figure 12 shows the von Mises stress profiles for the two samples. In Fig. 12A, the von Mises stress profiles for friction welding of 4340 steel to mild steel are shown and in Fig. 12B, profiles for friction welding of mild steel to mild steel are depicted. The asymmetry in the von Mises stress profiles seen in Fig. 12A in comparison with Fig. 12B is attributed to welding dissimilar materials (i.e., 4340 steel to
mild steel bars). In addition, the 4340 steel has more strength than the mild steel and therefore the von Mises stress in the right side of Fig. 12A is higher than that in the left side of the figure. In addition, a special pattern and characteristic exist in both figures and are described as follows: At a very far distance from the weld centerline, the von Mises stress is found to be similar to the von Mises stress of material at room temperature, since the effects of temperature and deformation on the material are negligible. At a closer distance to the weld centerline, in the heat-affected zone, the temperature increases and the yield stress at temperature decreases which, in turn, reduces the von Mises stress — Fig. 12A, B.

At a closer distance to the weld centerline, the increase of temperature produces more plasticity while the rest of the material resists against the deformation which, in
turn, increases the von Mises stress. At the weld centerline, where the two surfaces are in contact with each other, the von Mises stress reduces and the peak plastic strain increases due to temperature softening produced at the weld centerline. At distances away from the weld zones due to resistance of the material against the deformation, the von Mises stress increases. The von Mises stress obtained for the friction welding of 4340 steel to mild steel is found to be higher than that of mild steel to mild steel materials. This matter is attributed to friction welding of two dissimilar materials, which in turn produces more resistance to deformation due to the materials’ yield stress variations at temperatures.

The Strain Rate Distributions

The strain rate is an important physical parameter in plasticity. Therefore, the analysis was carried out to consider the strain rate distributions in the friction welding process. The most deformation occurred in the interface as a result of high transient temperature and subsequent material flowing. Figure 13A shows the strain rate distributions for friction welding of 4340 steel to mild steel materials, and Figure 13B illustrates the strain rate distributions for friction welding of mild steel to mild steel materials. Different strain rate patterns are obtained for friction welding of 4340 steel to mild steel and for mild steel to mild steel materials, respectively. In general, the strain rate of the order of $10^6$ observed for friction welding of 4340 steel to mild steel materials compared to the strain rate of the order 1 obtained for friction welding of mild steel to mild steel materials. Strain rate variations for the mild steel to mild steel friction weld are wider than those for the 4340 steel to mild steel friction weld. However, the figures show that the strain rate is zero at the weld interface due to temperature softening and might be positive and negative in the heat-affected zone, decreasing from zero to a minimum value and reaching again at $x = 0$, to rise to a maximum positive at the heat-affected zone. This variation of the strain rate is seen in modeling of all samples. The strain rate approaches zero at a far distance since no deformation occurred at distances away from the weld and HAZ zones. More fluctuation of the strain rate was observed in the material’s left-hand side than in the right-hand side. The reason is attributed to fixing of the right-hand-side bar and rotation of the left-hand-side bar. The strain rate fluctuations are increased with the bar rotation velocity.

Effects of Initial Pressure on Internal Parameters

Effects of Initial Pressure on Von Mises Stress

Figure 14 shows the effects of initial pressure on the von Mises distributions for friction welding of mild steel to mild steel.
Figure 15 shows the effects of initial pressure on the plastic strain profiles for friction welding of mild steel to 4340 steel bars when the final pressure is kept constant. The highest plastic strains occurred at the contact zones. Simulation results show that the plastic strain at the contact zone increases with the initial pressure. The numbers in the figure show the magnitude of plastic strain at the fusion zones. In addition, the figure shows that the fusion zones shift toward the fixed bar (to the right-hand side) by increasing the initial pressure, which in turn causes an increase in pressure and plasticity at the contact surface.

**Effects of Initial Pressure on Plastic Strain**

Figure 15 shows the effects of initial pressure on the plastic strain profiles for friction welding of mild steel to 4340 steel bars when the final pressure is kept constant. Three initial pressures were chosen — 0.8 (in yellow), 1.2 (in green), and 1 (in red) — times the initial pressure from Table 1. The numbers in the figures show the magnitude of von Mises stresses for that point. The simulation results show that all the diagrams follow similar patterns. Simulation results show that the von Mises stress increases with the initial pressure. Increase of pressure to the ratio of 1.2 causes the von Mises stress to increase about 50 MPa. The figure shows that the initial pressure does not affect the von Mises stress for the fixed bar (see the right-hand sides of the profiles in Fig. 14). Moreover, the magnitude of von Mises stress at the contact surface (fusion zone) increases with initial pressure. This matter is attributed to more hardening occurring in the fusion zones by increasing the initial pressure. In addition, Fig. 14 shows that the initial pressure of 16 MPa (0.8 P) is not sufficient to produce deformation and plasticity. It is also implied that the initial pressure is an important parameter that helps with plasticity similar to rotational velocity.

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**Effects of Final Pressure on Plastic Strain**

Figure 16 shows the effects of final pressure on the von Mises stress distributions for friction welding of mild steel to 4340 steel bars when the initial pressure is kept constant. Three final pressure ratios of 1.8, 2, and 2.2, to the defined final pressure in Table 1, were selected for simulations. Figure 16 also shows the von Mises stress along the rods.

Simulation results show that the final pressure does not significantly affect the von Mises stress obtained at the fusion zone and on the fixed bar. However, the von Mises stress increases slightly in the rotating bar with the final pressure. In other words, the HAZ von Mises stress increases in the rotating bar with the final pressure. Comparison between Figs. 14 and 16 reveals that initial pressure is a more important parameter than final pressure in affecting the von Mises stress.

**Effects of Final Pressure on Internal Parameters**

Figure 16 shows the effects of final pressure on the von Mises stress distributions for friction welding of mild steel to 4340 steel bars when the initial pressure is kept constant. Three final pressure ratios of 1.8, 2, and 2.2, to the defined final pressure in Table 1, were selected for simulations. Figure 16 also shows the von Mises stress along the rods.

Simulation results show that the final pressure does not significantly affect the von Mises stress obtained at the fusion zone and on the fixed bar. However, the von Mises stress increases slightly in the rotating bar with the final pressure. In other words, the HAZ von Mises stress increases in the rotating bar with the final pressure. Comparison between Figs. 14 and 16 reveals that initial pressure is a more important parameter than final pressure in affecting the von Mises stress.

**Effects of Final Pressure on Equivalent Strain**

Figure 17 shows the effects of final pressure on the equivalent strain distributions for friction welding of mild steel to 4340 steel bars when the initial pressure is kept constant.

The simulation results show that the effective strain distributions are not affected by the final pressure. Comparison between Figs. 14 and 17 reveals that initial pressure is more effective than final pressure on changing the effective strain profiles.

**The Proposed Experimental and Physical Welding Windows**

It is possible to draw a welding window based on the experimental parameters. The two most important experimental parameters are the rotational velocity and the initial pressure. It was found previously that the initial pressure is more important than the final pressure. Figure 18 shows the welding window for the 4340-mild steel combinations. In any welding window, minimum values of pressure and rotational velocity are required in order to produce the weld. If the initial pressure and rotational velocity are below these limits, there would not be enough plastic deformation to consolidate the weld. Moreover, there exists maximum pressure and rotational velocity. If the initial pressure exceeds a threshold limit, it may result in cracking and distortion of the materials. If the rotational velocity exceeds a threshold limit, it produces more heat at the temperature and more softening and may produce melt at the interface and, therefore, there would be no weld in the interface.

It is also possible to draw the numerical welding window based on the numerical parameters. It was found from this study that the most influential numerical parameters are the von Mises stress and the effective strain. Figure 19 shows the numerical welding window for the 4340-mild steel combinations. In the numerical welding window, it is not possible to draw a line of minimum and maximum von Mises and effective strain similar to what can be drawn for the initial pressure and rotational velocity welding window. This
Conclusions

Numerical calculations and experiments were performed to analyze the continuous friction welding process, which is a typical process with a high temperature, large deformation, and transient operation. The mathematical model of continuous friction welding is presented. The coupled effects of the mechanics and heat transfer are taken into account in the model. The distributions of temperature, deformation, von Mises stress, strain, and strain rate during the continuous friction welding process were numerically analyzed. The simulation results of temperature were in good agreement with the experimental points. The shape of the upset collar obtained from the simulations also fits excellently with those experimentally observed. With the finite element method (FEM) used in this paper, distribution of welding temperature, flow stress, and plastic strain and strain rate can be obtained. That means this model can be used as an industrial tool to predict evolution of temperature, stress, strain, and final geometry of the welded parts.

The following conclusions can be drawn from this study.

1. Simulation results predict a high value of plastic strain produced at the weld centerline due to increasing the temperature.
2. Similar trends to those obtained for the plastic strain distributions are obtained for the temperature distributions.
3. The peak von Mises stress is produced at distances away from the weld centerlines.
4. The von Mises stress reduces in the fusion zone due to temperature softening.
5. The von Mises stress obtained for friction welding of 4340 steel to mild steel is found to be higher than that achieved for friction welding of mild steel to mild steel materials. This is attributed to friction welding of two dissimilar materials, which in turn produces more resistance to deformation, and is also due to the materials yield stress variations at temperatures.
6. A very fine grain structure is produced at the weld zone, which in turn causes the higher strength according to the Hall-Petch relation.
7. The results of the tensile test predict that the weld zone is stronger than the base metals since the rupture occurred outside of the welding area.
8. The shape of the upsetting obtained from the simulation is similar to that achieved from the experiments.
9. The initial pressure is a more effective parameter than the final pressure on changing the von Mises stress and equivalent strain distributions.

The experimental and numerical welding windows are proposed to determine the operational and numerical parameters to produce the weld.

References


Call for Papers

2008 World Standards Day Competition

Sponsored by the Standards Engineering Society (SES), the theme for this year’s paper competition, “Intelligent and Sustainable Buildings,” recognizes the critical role of standards and conformity assessment programs in ensuring safety requirements; facilitating coordination among contractors, builders, engineers, and architects; and incorporating new technologies in design and construction. The competition invites papers that use specific examples to show ways that standards and conformity assessment programs are used for intelligent and sustainable buildings.

All paper contest submissions must be received with an official entry form by midnight on August 29, 2008, by the SES Executive Director, 13340 SW 96th Avenue, Miami, Florida, 33176. For details on the winners’ recognition, cash awards, judging, and rules, go to www.ses-standards.org and follow the link for WSD Paper Competition 2008.
A Friction-Based Finite Element Analysis of Ultrasonic Consolidation

In this study, the contribution of friction to the bonding mechanism in ultrasonic welding is explored, and offered are the distributions of temperature and plastic deformation caused by the friction stress.

BY C. ZHANG AND L. LI

ABSTRACT: Surface bond formation in ultrasonic consolidation is a complicated thermal-mechanical coupled process. Friction and plastic flow are used to simulate the bond interface behavior. This paper focuses on the contribution of friction to the bonding mechanism in ultrasonic welding. Based on a 3-D thermomechanical quasi-static finite element model, the distributions of temperature and plastic deformation caused by the friction stress are presented. Temperature and plastic deformation are found to vary with vibration cycles. A saturation phenomenon is identified that after a certain number of vibration cycles, the plastic deformation caused by the friction stress reaches a steady state.

Introduction

The ultrasonic consolidation (UC) process is designed to continuously weld layers of metal foil to previously deposited layers, during which the profile to each layer is created by contour milling, to build up a 3-D structure. As with ultrasonic welding, most commercially available metal foils, such as aluminum, titanium, magnesium, copper, and steel, can be used in the UC process (Refs. 1, 2).

One area that will benefit from an improved understanding of ultrasonic bonding is the fabrication of metal matrix composites (MMCs). Continuous fiber-reinforced MMCs are typically produced by using powder metallurgy or pressure-assisted casting methodologies (Ref. 3). The appropriate design and application of MMCs depends on how easily they can be fabricated. The ability to model their properties accurately is one of the keys to the effective implementation of MMCs in new and existing applications.

As a joining method, ultrasound bonding is arguably the least understood. However, realization of the full potential of ultrasonic bonding will require a greater understanding of the mechanisms for bond formation. No systematic simulation results and analysis have been published on ultrasonic bonding, especially those of the interface between the top layer of the foil and the substrate that is believed to be the most important region where bonding occurs. Most research of UC assumes that friction and plastic flow can be studied to understand the most fundamental phenomena at the interface in ultrasonic welding (Refs. 2, 4–9). The friction is attributed as the shear effect on bonding, while plastic deformation is attributed as the process in which the bond forms. Diffusion is also suggested as a possible process for bond formation; however, the relatively low temperature and short time during the rapid bonding process seem to make diffusion insignificant for bond formation.

Coupled Physical Phenomena in Ultrasonic Consolidation

The bond formation between the foil and substrate in UC is still unknown to researchers because of the complicated interactions of vibration, deformation, friction-like shear, localized thermal effect, and oxides/contaminants dispersion on the interface. The modeling of ultrasonic consolidation of metals and alloys began only recently with the development of emerging new technologies that employ ultrasonic welding in ultrasonic consolidation. The weld strength of UC was modeled and an empirical model was derived on the basis of the theory of surface and volume effects by Kong et al. (Ref. 10). A 2-D spot-welding model for the mechanical field was also constructed, and the variation of friction coefficient during the process was measured and studied in detail by Gao and Doumanidis (Ref. 11). Their results pointed out the role of friction and pressure in the formation of the elastic strain field at the bond region. However, since the heat equation was not included in their analysis, the results did not include any thermal effect.

This paper attempts to present the effect of friction on the bonding interface by applying Coulomb’s law of friction, and assumes that, under the vibration load, the interface material will go through the localized elastoplastic deformation under the friction heating process.

During ultrasonic consolidation, the behavior of the bonding interface can be described as follows: 1) The sonotrode vibrates at a fixed frequency transversely to the direction of sonotrode travel (Fig. 1) and a constant pressure is applied through the sonotrode; 2) the friction at the contact surface area will break the surface contaminants, such as oxides, so as to build an intimate contact condition; 3) the ultrasonic vibration generates a localized elevated-temperature zone at the contact surface, which will dramatically reduce the critical shear stress; and 4) shear strain in turn will generate heat and affect the friction conditions. Therefore, the ultrasonic consolidation is a continuous process in which the generation of strain in the mechanical field and temperature in the thermal field are interactive. Thus, the UC process constitutes a typical coupled-field problem.

The analysis strategy for ultrasonic consolidation as a coupled-field problem is outlined in Fig. 2. It can be seen that in the

KEYWORDS

Numerical Model
Ultrasonic Consolidation (UC)
Friction
Thermal-Mechanical Analysis
Plastic Strain
Bond Formation
mechanical field the strain and stress are determined by the pressure load, fiction force, and temperature-dependent material properties. In the thermal field, the temperature is assumed to be mainly influenced by the heat generated by friction. The fiction coefficient and material mechanical properties vary with temperature, which in turn affect the heat generation.

Two routes are believed to couple the mechanical and thermal fields in ultrasonic consolidation: 1) The thermal field affects the mechanical field, because most of the material mechanical properties, such as modulus of elasticity, yield strength, and fiction coefficient, are temperature sensitive; and 2) the mechanical field (the friction force) generates heat, which changes the thermal field. During simulation, these varying material properties and quantities at the last time step must be determined for calculating the state at the current time step.

Finite Element Analysis

For the purpose of understanding the role of friction in UC and its contribution to the bond formation, a 3-D coupled-field nonlinear model has been developed and a dynamic finite element analysis has been conducted based on the ANSYS package.

Theoretical Background

In the ANSYS mechanical analysis, the stress and strain relationship is as follows:

\[
\{\sigma\} = [D] \{\varepsilon^{el}\}
\]  

(1)

\[
\{\varepsilon^{el}\} = \{\varepsilon\} - \{\varepsilon^{pl}\} - \{\varepsilon^{th}\}
\]  

(2)

where \{\sigma\} is stress vector, [D] is elastic stiffness matrix, which is a function of temperature, \{\varepsilon^{el}\} is elastic strain vector, \{\varepsilon\} is total strain vector, \{\varepsilon^{pl}\} is plastic strain vector, and \{\varepsilon^{th}\} is thermal strain vector.

The bilinear von Mises yield criteria are used in this model. If the von Mises equivalent stress is less than the material yield strength at temperature, the stress state is elastic and no plastic strain is computed. If the stress exceeds the material yield strength, the plastic strain is calculated by...
where \( \lambda \) is the plastic multiplier (which determines the amount of plastic straining) and \( Q \) is the yield function. As the material yields, the yield surface changes due to the bilinear isotropic (work) hardening.

To find out the effect of sonotrode’s cyclic motion, a transient dynamic analysis is conducted on the model. The governing dynamic equation is as follows for a linear structure (Ref. 14):

\[
\begin{bmatrix}
\frac{\partial^2}{\partial t^2} u \\
\frac{\partial}{\partial t} u \\
u
\end{bmatrix} = \begin{bmatrix} M & C \\
C & K \end{bmatrix} \begin{bmatrix}
\frac{\partial^2}{\partial t^2} u \\
\frac{\partial}{\partial t} u \\
u
\end{bmatrix} + \{ Fa \} \quad (4)
\]

The nonlinear analysis in this model is proceeded by updating these matrices computed from the temperature-dependent material properties and conducting a linear analysis for each step.

In the ANSYS thermal module, conduction heat flow is included in the FEM model and the governing equation is as follows:

\[
\rho c \frac{\partial T}{\partial t} + (\mathbf{v} \cdot \nabla) T = q + \nabla \cdot ((K \cdot \mathbf{v}) T) \quad (5)
\]

where \( \rho \) is density, \( c \) is specific heat, \( T \) is temperature, \( t \) is time, \( \mathbf{v} \) is velocity vector for mass transport of heat, \( q \) is heat gen-
peration rate per unit volume, \( K \) is conductivity vector, and \( V = \frac{\partial}{\partial x} + \frac{\partial}{\partial y} + \frac{\partial}{\partial z} \).

In the ANSYS thermomechanical coupled analysis, the thermal-structural coupled finite element matrix equation derived from the stress equation of motion and the heat flow conservation equation coupled by the thermoelastic constitutive equations is as follows (Ref. 14):

\[
[M] \{\dot{u}\} + [C] \{ \dot{u} \} + [K] \{ \dot{T} \} + [C_t] \{ F \} + [K_t] \{ Q \} = 0 \tag{6}
\]

where \([M]\) is the element mass matrix, \([C]\) is the element structural damping matrix, \([K]\) is the element stiffness matrix, \(\{u\}\) is the displacement vector, \(\{F\}\) is the sum of the element nodal force, \([K^0]\) is the element specific heat matrix, \([K^1]\) is the element diffusion conductivity matrix, \(\{T\}\) is the temperature vector, \(\{Q\}\) is the sum of the element heat generation load and element convection surface heat flow vectors, \([K^u]\) is the element thermoelastic stiffness matrix \((-\int_{vol} [B]^T \{\beta\} \{\nabla (N)\}^T \, d(vol)\)\), \([B]\) is the strain-displacement matrix, \([C_{tu}]\) is the element thermoelastic damping matrix \((-T_w[K^u]^T)\), \(T_w\) is the absolute reference temperature \((= T_{ref} + T_{off})\), \(T_{ref}\) is the reference temperature.

**Finite Element Model**

Figure 3A shows the 3-D UC model with the sonotrode located at the center of the baseplate. The dimensions of the baseplate and cylindrical sonotrode are the same as the experimental setup: 355.6 \times 355.6 \times 12.7 mm and 146.1 mm (diameter) \times 25.4 mm (thickness). Compared with the baseplate and sonotrode, the aluminum foil is much smaller (25.4 mm width and 0.1 mm thickness). Since this model has two symmetrical planes (Plane X = 177.8 mm and Plane Y = 177.8 mm) and the large difference in dimensions exists between the foil and baseplate/sonotrode, a UC model with quarter size has been built and shown in Fig. 3B. This model is used to simulate the bonding of the first layer. Because the foil is very thin and the sonotrode has a roughened surface, it is assumed that a no-slip condition exists between the top surface of the foil and the sonotrode. The friction is assumed to occur between the bottom surface of the foil and the substrate. The 3-D coupled-field meshed model (Fig.
3C) involving the sonotrode that is in close contact with and vibrates against the substrate has been developed. The meshing around the contact area is refined following a meshing study. The type of elements used in simulation and their functions are listed in Table 1. The number of total nodes and elements is 14722 and 10251, respectively.

Material Properties

Tensile tests have been conducted on the Gleeble 1500D thermal-mechanical simulator for measuring the temperature-dependent mechanical properties of aluminum foil (Al 3003-H18) used in this study. The dimensions of test samples are 22.0 x 10.1 x 0.1 mm, and the tensile load rate is 1.2 mm/min. Specimens were heated to various temperatures and held for 3 min for thermal equilibrium, and tensile pulled. The results are listed in Table 2. It is seen that the properties of aluminum material are very sensitive to the temperature. At the preheating temperature (150°C), the mechanical properties decrease to the half or even less of those at room temperature. The measured yield strength data of aluminum foil are different, but close to those from the reference. The composition and thermal properties for Al 3003-H18 are shown in Tables 3 and 4.

Coulomb’s law of friction is used to simulate the friction-like shear force on the bonding interface. Since the pressure is constant in the process, the friction coefficient is the only factor determining the magnitude of friction. Experiments for measuring the Al-Al friction coefficient have been designed and conducted on the Gleeble 1500D. Figure 4 shows the device setup. The fixed anvil is covered with foil of Al 3003-H18 and another foil is put between them. A normal force (N) is applied on the top anvil. When a certain uniform temperature is achieved by the heating and controlling system of the Gleeble, the middle foil is pulled out at a certain rate (sliding speed). The sliding speeds between 1 and 1000 mm/s are tested. The friction occurs on the top and bottom surfaces of the foil pulled out. Therefore, the Al-Al friction coefficient at the testing temperature can be calculated by $\mu = F/2(N + W)$, where $F$ is the measured pulling force, and $W$ is the top anvil’s weight and pressure. Friction coefficient of Al-Al varying with temperature is shown in Fig. 5. There is no significant effect of sliding speeds, in the range tested, on the friction coefficient.

The model in this paper has included the material nonlinear effects by using the data in temperature-dependent mechanical properties tables above. In the transient dynamic analysis, the mechanical properties for different locations on the contact surface are different depending on the local temperature and are input to the model for each step.

Boundary and Initial Conditions

The UC process parameters, including pressure load (1800 N), preheating temperature (150°C), vibration amplitude (16 μm), and vibration frequency (20 kHz), are incorporated in the model as boundary conditions. The pressure load and vibrational displacement are applied to the interface of foil and baseplate. A triangle wave is used to approximate the sinusoidal waveform of the ultrasonic vibration. The measured contact area under 1800 N is 4.7 mm along the direction of the sonotrode’s moving, and the sonotrode’s speed in UC process is 28 mm/s. For a given point underneath the sonotrode, the maximum time of contact is approximately 0.16 s, or about 3000 cycles of vibration. Therefore, we assume a stationary sonotrode in the model, and the maximum number of cycles to be modeled is 3000.

A fixed boundary condition for displacement is applied to the baseplate’s bottom surface and all corners except the surface contacting the sonotrode. Symmetrical boundary conditions are used on two symmetrical planes. A uniform initial preheating temperature is applied to the parts around the bonding surface, including the sonotrode, baseplate, and foil. No convective heat loss from baseplate and sonotrode to air is assumed because the UC device is in an enclosed space in which there is no significant air flow. The radiation heat loss is also ignored due to the low temperature range.

Methodology of Finite Element Analysis for UC

Because of the limit of capability of the ANSYS thermomechanical coupled element, no plastic results can be obtained from the thermoelastic equation. Therefore, the strategy for simulation involves calling appropriate analysis modules: 1) Conduct a thermoelastic analysis using the thermomechanical coupled element for friction heat generation; 2) output the temperature data for each node; 3) change the element type to the mechanical element; 4) apply the temperature load on each node; and 5) conduct a mechanical analysis and output the plastic results. A flowchart that outlines the analysis procedures is given in Fig. 6. A further simplification involves that the plastic deformation is assumed to have no effect on the friction heat generation, and that no plastic heat is generated in the entire process.

Simulation Results

Effect of Friction on Temperature

Figure 7 shows the coordinate plane projections of temperature distribution on the contact surface (bond interface) at the 1500th vibration cycle. With friction heat, a uniform peak temperature state exists on the contact surface, and the temperature decreases away from the contact surface into the substrate. The temperature distribution shows a cylindrical symmetry about the center of the contact surface.

The average temperature due to friction at the contact surface increases rapidly with the number of vibration cycles in the initial period of bonding. As the welding time is longer (higher number of cycles), the temperature rise slows down, and seems to approach a steady state — Fig. 8. The increase of interface temperature is influenced by $q_{\text{friction}} - q_{\text{loss}}$, where $q_{\text{friction}}$ is the friction heat generation rate, $q_{\text{loss}} = k \Delta T$ is the heat dissipation rate by conduction. At the beginning of UC bonding, the rate of friction heat generation is much higher than that of heat loss, because initially the temperature difference ($\Delta T$) is low. As the temperature becomes higher due to friction heating, two com-
peting factors become significant: On the one hand, the decrease of Young’s modulus (Table 2) and friction coefficient (Fig. 5) will slow down the friction heat generation; on the other hand, the greater temperature difference enhances faster heat dissipation. Therefore, the temperature increase slows down. A balance between $q_{\text{friction}}$ and $q_{\text{loss}}$ can be achieved eventually, giving rise to $q_{\text{friction}} - q_{\text{loss}} = 0$, i.e., a thermal steady state. Physically, if the heat loss is faster than the friction heat generation and the interface temperature decreases, the higher values of Young’s modulus and friction coefficient at the lower temperature will automatically increase the $q_{\text{friction}}$ until a new dynamic heat balance is achieved.

Effect of Friction on Plastic Deformation

Three paths (A-B, A-C, and A-D) have been selected to show the three-dimensional distributions of von Mises strain around the contact surface where the bonding process happens — Fig. 9A. Figure 9B shows the von Mises strain distributions along path A-B (the vibration direction) as a function of the number of vibration cycles. At the beginning of bonding (50th cycle), the plastic strain is relatively small. The highest plastic strain occurs at the edge of the contact surface near point B. By the 350th cycle, the plastic strain in the center of the contact surface exceeds the level of plastic strain at the edge. After the 500th vibration cycle, the value and distribution of plastic deformation reach a steady state, when there is no change in von Mises strain with further increase of the vibration cycle. The maximum plastic strain is located at point A, the center of the contact surface. A wavy-shaped plastic strain distribution caused by the cyclic vibration is apparent. The reason for such characteristic wave shape distribution of deformation has been studied and explained by superposition of vibration waves in Ref. 9.

A similar plastic strain distribution can be seen along path A-C (the depth direction). In Fig. 9C, a small region close to point A has a plastic strain level higher than 1 after 500 vibration cycles. The depth direction plastic strain in all other regions along path A-C is lower than 0.1. Since the depth direction plastic strain is the easiest to measure experimentally, it will be used for verification of the model later.

Path A-D is perpendicular to the sonotrode vibration; therefore, there is no waveshape deformation distribution (Fig. 9D) as seen along path A-B. A steady increase of plastic strain levels can be seen as the number of cycles increases. The steady-state strain distribution indicates a peak level close to point A.

The evolution of the average von Mises plastic strain on the contact surface as a function of time (or vibration cycle) is shown in Fig. 10. It has the same trend as the temperature vs. vibration cycle in Fig.
8. The average plastic strain also approaches a “steady state” at the 1000th vibration cycle when the contact surface average temperature is close to the steady state. The time to reach the steady state for the average plastic strain is later than that for the three paths defined in Fig. 9.

In the initial period when the temperature is increasing, the yield strength of material in the contact area decreases. When the von Mises stress at any location reaches the yield condition at certain specific temperature, the material yields and plastic deformation occurs. When the friction heat generation on the interface balances the heat loss and the average temperature approaches the steady state, the increase in plastic deformation stops and a similar steady state is also achieved. The number of cycles to reach this steady state may decrease (or the time may be shorter) when plastic deformation heat is considered in addition to the friction heat.

One important experimental observation in UC is that the strongest bonding is only achieved with an optimized travel velocity of the sonotrode. Too fast travel velocity does not provide enough dwell time (or number of vibration cycles) for bonding; while too slow a travel velocity does not result in good bonding either. The evolution of temperature and plastic strain obtained in this study can help quantitatively understand the phenomena, and provide control strategies for stronger bonding.

**FEM Model Validation**

**Definition of Z-Directional Compressive Equivalent Plastic Strain in Experiment**

An experimental validation of the finite element results shown in Fig. 9C was conducted. In UC, the height of deposit is smaller than the sum of foil layers’ original thickness, and the relative ratio is changing with the number of layers. Figure 11 shows the difference of substrate’s height before bonding (A) and after bonding (B). Thus, the z-directional compressive equivalent plastic strain can be defined as follows:

\[ \varepsilon_{eq}^{z} = \frac{(H_a - H_b)}{H_b} \]  

(7)

Samples of various numbers of layers are made on the UC machine with the same process parameters used in the simulations. The sample heights after UC bonding are measured with a precision height gauge with a 0.001-mm resolution. The substrate’s height before bonding is calculated by 0.1 mm (foil thickness) × 8 (layer’s number). Thus, the z-directional compressive
equivalent plastic strain from the experiment can be calculated by Equation 7.

**Definition of Z-Directional Compressive Equivalent Plastic Strain in Simulation**

For the purpose of finite element model validation, a new finite element model is developed to incorporate a rectangular substrate 12.2 mm long and 5.0 mm wide — Fig. 12A. The same simulation strategy is applied to the new simulation with various buildup layers. A cut section plane parallel to the vibration direction and located at the center of the substrate is chosen for extracting the z-directional plastic strain. Figure 12B shows the distribution of z-directional plastic strain in the cut section for the eight layers of the substrate. The average value is calculated and defined as the z-directional compressive equivalent plastic strain in simulation.

**Comparison**

Figure 13 shows the comparison of z-directional compressive equivalent plastic strain between experiment measurement and finite element simulation. It can be seen that the finite element model in this paper is able to correctly predict the trend and magnitude of the experimental data. The error may be very likely due to the omission of contribution of plastic heat flux to plastic strain. Another error source is the use of solid substrate in the validation model instead of the true substrate. The plastic strain has a characteristic waveform distribution that is caused by the superposition of vibration waves.

2. The plastic strain is believed to contribute to bond formation of the ultrasonic consolidation. Similar to the temperature field, the plastic strain field also approaches a steady state after a certain number of vibration cycles. The peak level of the plastic strain is located near the center of the contact surface between the top foil and substrate. The plastic strain has a characteristic waveform distribution that is caused by the superposition of vibration waves.

3. The model has been reasonably verified by experimental measurement. The results are able to provide insights for understanding the mechanisms of bond formation for ultrasonic consolidation, and for guiding experimental design for stronger ultrasonic bonds.

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**References**


14. ANSYS, Inc. Release 11.0 Documentation for ANSYS.

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