Winter 2007 | Volume 19.4.1

Insights

MP crimping example (2" Al 6061 seamless tube on a contoured steel fitting)

2mm Folded DRW end-form and an eyelet used to simulate the stabilizer bar assembly

DRW suspension link application

Advanced Welding Techniques for Joining Tubular Structures

Jonathan Jennings | Automotive Business Development Manager

Tubular structures can offer significant improvements with respect to performance, weight, and cost. To date, their use in car frames is hindered by the lack of appropriate joining technology for thin-wall tubes.

Joining technologies like gas metal arc welding (also known as MIG welding), gas tungsten arc welding (also known as TIG welding), laser welding, etc., create challenges when welding large volumes of tubular structures. The challenges include the need to move the welding heat source and/or filler metal source around the weld joint in tight spaces, and issues with burn-through. These processes create even greater challenges in the welding of tubular structures made of coated materials in joining dissimilar materials.

EWI and SpaceForm are involved in the development of two new technologies designed for tubular structure joining; deformation resistance welding (DRW) and magnetic pulse (MP) joining technology.

DRW is a resistance welding process which uses conventional resistance welding machines and forms near instantaneous, leak-tight welds. DRW was developed for tube-to-tube joints but can also be used in other applications such as tubes welded to sheet metal or to a heavy section part.

Because DRW makes welding thin-wall tubes less difficult and less expensive; it enables lower cost products with decreased weight and increased structural integrity. EWI is currently developing automotive space frame structures using DRW. These structures are mostly composed from 3D cast steel nodes connected by DRW to high strength tubes, forming a space frame. DRW weldability studies of some advanced high strength steels such as DP 780, DP 980, and TRIP 780 are a part of the work.

MP joining configures two tubular parts to form a lap-type joint. The basic requirement of the process is that the outer tube is electrically conductive and possesses certain amounts of plastic deformation capability. The inner tube can be a different material that is either conductive or non-conductive. The passage of a high current discharge thorough the specially designed coil (or coil bank) creates a large electro-magnetic force that causes the outer tube to impact the inner tube at a velocity sufficiently high enough to generate bonding in a matter of microseconds. This powerful repulsion force causes the outer tube to impact the inner tube at a velocity that is sufficiently high to generate bonding in a few milliseconds.

MPW development work at EWI includes the welding of dissimilar materials for auto structures and chassis applications such as aluminum to steel. The MP joining technology and DRW processes will enable product designers to extensively use tubular structures for vehicle performance improvement and weight reduction.

For more information on EWI's DRW and MP projects, contact Jon Jennings at 614.688.5144 or jon_jennings@ewi.org.

The President's Corner

Client Impact | Every client has a story—and through the work done at EWI—these stories usually have happy endings. From advanced development services to advancing the science of friction stir welding, the work of our engineers positively impacts our clients. In fact, making a difference for our customers is a guiding principle at EWI–one of four that I'll be covering over the coming months in future issues of the newsletter.

Since 1984, EWI has been striving to make a meaningful difference to our clients' businesses. Indeed the guiding philosophy behind our company is to advance and apply materials joining technology to benefit our customers. When we do this well, we provide our members a competitive edge. But, what does that mean?

To help answer that question, this issue highlights how we've helped one client make a quick, but well-founded, and potentially money-saving decision. Because our staff and engineers took the time to understand the automotive supplier's business, they were able to quickly and objectively make recommendations on system requirements and offer a lower cost alternative to assure a quick implementation in the production process.

Recently, we announced in conjunction with the American Welding Society (AWS) that EWI has joined the American Council of the International Institute of Welding (IIW), which enhances North America's involvement and role in the IIW and strengthens EWI's representation of the welding industry internationally. Given the global nature of our client base, we expect this leadership opportunity for EWI to also have a positive impact on your business – now or in the future.

We are also announcing our biennial conference. EWI and our partners, including Ohio State's Welding Engineering program will hold the conference, "Materials Joining; Building for the Manufacturing Future" May 8-9, 2007 in Columbus, Ohio, at the Greater Columbus Convention Center, and will highlight EWI's multifaceted technologies including new joining processes, repair technologies, and nondestructive evaluation. It is designed for managers and engineers in various industries including automotive, light manufacturing, aerospace, energy, power generation, pipeline, heavy manufacturing, electronics and medical devices. I hope you will consider attending the conference so you can learn about some of our most recent technological innovations and how they might help you.

Henry Cialone

But, you don't have to wait until May to find out about some of these innovations. If you visit the EWI Member Central website, you will find our latest Cooperative Research Project reports, including Numerical Simulation of Forming of Advanced Materials, Development of Weldability Test for High Performance Nickel-Base Alloys, and High-Speed Laser Welding of Thin Steels; or better yet, exercise your EWI membership and come see us for a personal preview.

As you can see from this issue, our number one focus is to make a meaningful contribution to our clients' businesses – something we refer to as "client impact." Our dedicated and professional staff aim to make a lasting impact for our clients with every project we undertake. Please contact us so we can provide a happy ending to your story.

EWI Hires Mr. Brian Bishop as Aerospace Business Development Manager

Brian Bishop

EWI has announced that Mr. Brian Bishop has joined the company as an Aerospace Business Development Manager. Mr. Bishop brings over 25 years of experience in the aerospace industry.

As Aerospace Business Development Manager at EWI, Mr. Bishop will focus his experience on bringing value-oriented solutions that address the materials joining challenges facing the aerospace industry. He is responsible for business development in the aerospace market and related product development activities for EWI.

He previously served as a Sales Executive with General Tool Company, a precision machining, fabrication, tooling, die, mold, and assembly manufacturer. Over the years, he also held positions as Business Unit Manager, Sales Engineer, and Project Manager at General Tool Company. For the last five years, Mr. Bishop led the Engineering Tooling and Assembly Division as they designed, built, and installed FSW machines for NASA, Rockwell, and EWI. This equipment is some of the largest and most capable in the Country serving very demanding applications and research. This same team also was a key supplier (> $20mm) for Lawrence Livermore National Labs in their efforts to build the largest laser in the world; the National Ignition Facility (NIF).

Mark Your Calendar:

Friction Stir Welding Technology
for Defense Applications Workshop

The third in a series of friction stir welding workshops will be held February 21-22, 2007 at EWI in Columbus Ohio. This workshop is sponsored by the Navy Manufacturing Technology Program, Office of Naval Research and organized by the Navy Joining Center and Navy Metalworking Center. This workshop will provide industry and the Department of Defense with the latest advancements in the development and implementation of friction stir welding technolgy for defense applications. Due to ITAR restrictions, workshop participation is limited to U.S. citizens with an approved DD2345. For further information or to register for this conference please contact Connie Kotula at 614-688-5156 or by email at **connie_kotula@ewi.org**.

Save the Date

May 8-9, 2007

EWI Presents

Materials Joining:
Building for the Manufacturing Future

May 8-9, 2007
Greater Columbus Convention Center
500 North High Street
Columbus, Ohio 43215

Watch for updates on our website, **www.ewi.org**

EWI Success Story

Challenge
TRW Automotive, headquartered in Livonia, Michigan, supplies more than 40 major vehicle manufacturers with products that include integrated vehicle control and driver assist systems, braking systems, steering systems, suspension systems, occupant safety systems (seat belts and airbags), electronics, engine components, fastening systems and aftermarket replacement parts and services. TRW asked EWI to perform a comparison of power supplies for projection welding ball joint canister shells to lower arm assemblies for suspension components.

Solution
The initial work in this program considered different power supply types to achieve the desired projection welds. EWI examined performance of welds made with each power supply type and chose the best technology for this application. EWI made recommendations on system requirements, and how that system would be implemented in production. The process EWI recommended was also found robust to variations in set-up condition, alignment, etc.

Results
Large-scale projection welding equipment is both capital and lead-time intensive. The results of this program allow such a capital decision to be confidently made, assuring quick implementation as a production process.

"The work done by TRW in conjuction with EWI provided the customer with a confidence level, both in our objective approach to the processing parameters and in TRW's choice of expertise partner," said John Thompson, Manager-Advanced Engineering at TRW.

Insights is produced four times per year. Please direct general questions and comments to Lisa McClintock, Marketing Communications Manager, at 614.688.5130 (lisa_mcclintock@ewi.org). Questions relating to an article may also be directed to the contact listed in the article.

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Assessment of Tool Materials for Friction Stir Welding of Hard Materials

Friction stir welding technology has been extensively implemented in the production of aluminum structures. Aluminum structural components for space vehicles, aircraft, automotive, and naval applications have been successfully manufactured using the FSW process. However, the application of FSW on high-temperature alloys such as steels has not progressed as far as that for aluminum alloys due to the difficulty in finding pin tool materials able to withstand the temperatures and loads during FSW. Recent advances in the capabilities of pin tool materials have renewed the interests of FSW high-temperature alloys from various industries including aerospace, shipbuilding, automotive, and petrochemical industries.

Approach

This project evaluated the performance of both refractory alloys and ceramic-based tool materials for FSW of hard metals. The evaluated refractory alloys included commercial pure tungsten (CPW) and tungsten-rhenium alloy (W-25%Re). CPW is readily available and fairly affordable compared with other tungsten alloys. W-25%Re alloy is one of the highest strength tungsten alloys. The W-25%Re rod used in this study was in the P/M condition. The examined ceramic material was polycrystalline cubic boron nitride (PCBN) — the second hardest material known to man.

The materials welded in this study included L80 and X70 high-strength pipe steels commonly used in the petrochemical industry. The nominal compositions of these materials are shown in Table 1.

Table 1. Nominal Chemical Compositions of L80 and X70 Steel

Element, wt%	C	Si	Mn	Ni	Mo	Cr	V
L-80	0.32	0.35	1.2	0.2	0.65	1.3	0.05
X-70	0.09	0	1.45	0.5	0	0	0.08

L80 and X70 plates were friction stir welded using CPW, W-25%Re, and PCBN pin tools (patented by Tracy Nelson, et al). Pin tools were examined in terms of dimensional stability including wear and deformation (creep). L80 and X70 welds made with PCBN tool were conducted at MegaStir, West Bountiful, Utah.

L80 and X70 friction stir welds were characterized in terms of tensile and Charpy impact tests. Tensile tests were conducted at room temperature and Charpy impact tests were carried out at 19˚ F (-7˚ C).

Results and Discussion

There was severe wear and deformation on the CPW pin tool after 10-in. long weld on L80 plate as shown in Fig. 1, evidence that CPW is not a viable tool material for FSW of steels.

The appearance change of the W-25%Re pin tool after a 10-in. long weld on L80 plate is presented in Fig. 2. The W-25%Re

Figure 1: CPW pin tool: (a) Prior to weld; (b)after 10-in. long weld

Figure 2: W-25%Re pin tool: (a) Prior to weld; (b)after 10-in. long weld

Figure 3: PCBN pin tool after 60-in. long weld

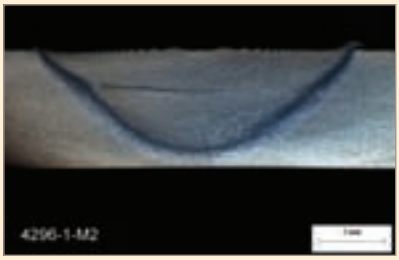

Figure 4: Macrograoh of L80 friction stir weld made using CPW tool

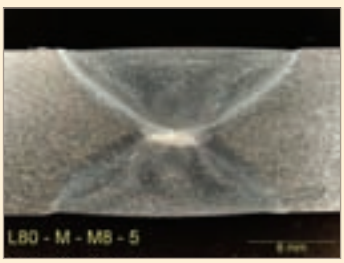

Figure 5: Macrograoh of L80 friction stir weld (two pass weld) made using PCBN tool

pin tool performed very well with no visual change in appearance after welding. However, there were slight reductions in the pin dimensions and shoulder length when measured with a caliper. The weld cross section was examined using a scanning electron microscope (SEM) with energy dispersive spectrum (EDS). The result indicated that there was a minor amount of tool material debris in the weld.

Fig. 3 shows a PCBN pin tool after 60-in. long weld that includes 30-in. long L80 weld and 30-in. long X70 weld. There was no visual evidence of wear on the PCBN pin tool. Because boron and nitrogen are light elements, it is difficult to detect boron nitride debris in the weld using SEM with EDS. Deformation (creep) of PCBN pin tools is not an issue due to its extraordinary high hardness. However, several cracks were found on the shoulder of the pin tool due to its brittle nature.

Representative macrographs of L80 friction stir welds made using CPW and PCBN pin tools are presented in Figures 4 and 5, respectively. Full 0.5-in thick single-sided welds were made using the tungsten-based tools while the PCBN tool welds were double pass welds. The horizontal line in the CPW weld micrograph is a metallurgical phenomenon not a lack of consolidation defect.

Room-temperature tensile properties of welds made using CPW and PCBN pin tools matched L80 base material properties as shown in Fig. 6. High heat input FSW made with PCBN tool (FSW-H PCBN) showed lower ultimate tensile strength (UTS) and elongation due to a weld surface defect that resulted in a premature failure.

Fig. 7 presents ultimate tensile strength (UTS), yield strength (YS), and elongation of X70 base material and welds made with W-25%Re and PCBN pin tools. Again, the friction stir welds matched X70 base materials properties.

The toughness of the FSWs was much lower than L80 base material as seen in Fig. 8. Formation of overwhelming amount of martensite in the stir zone is the cause of the brittleness of the welds for L80 FSW. For three welds (WCL-L PCBN, WCL-M PCBN, and WCL-H PCBN) made with the PCBN tool using three different heat inputs, lower heat input resulted in higher toughness in the weld centerline, although the heat input did not affect the tensile properties, except for elongation. The toughness values of the welds at the HAZ can only serve as a reference because it is difficult to accurately locate the HAZ location.

On the other hand, the toughness of the welds was much higher than X70 base material as shown in Fig. 9. Lower carbon content in X70 has avoided formation of large amounts of martensite formation during FSW process; therefore, much higher toughness of FSW has benefited from grain refinement in the stir zone.

Conclusions

- CPW is not a viable tool material for FSW steel due to its severe wear and deformation.
- W-25%Re pin tools performed much better than CPW tools in FSW of steels (L80 and X70) in terms of tool wear and deformation. However, there was still some wear on the W-25%Re tool after FSW L80 and X70 steels.
- The PCBN tool had no deformation issue and no visible wear. However, PCBN tools are brittle and have very high requirements on the stiffness of FSW machine and spindle run-out.
- FSW tensile properties of both L80 and X70 friction stir welds matched L80 and X70 base materials properties, respectively.
- Charpy impact results showed that L80 FSW had much lower toughness than base material due to the large amount of martensite in the stir zone. X70 FSW exhibited much higher toughness than base material due to the formation of tough phases in the stir zone.

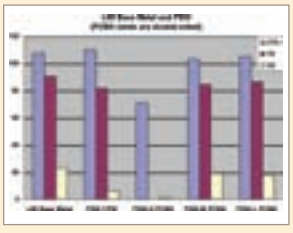

Figure 6: Tensile properties of L80 base material and FSW

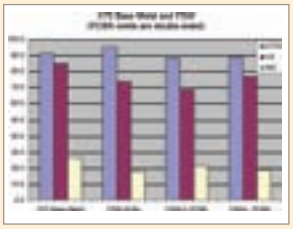

Figure 7: Tensile Properties of X70 base material and FSW

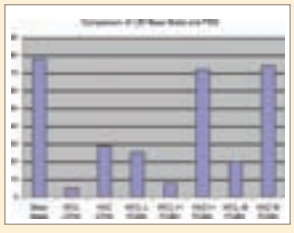

Figure 8: Charpy test results of L80 base material and FSW

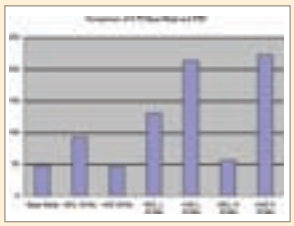

Figure 9: Charpy test results of X70 base material and FSW

Edison Welding Institute Joins American Council of the International Institute of Welding

The American Welding Society (AWS) and Edison Welding Institute (EWI) announced that EWI has joined the American Council of the International Institute of Welding (IIW), a committee that includes AWS and the Welding Research Council (WRC) that represents the United States welding industry. The addition of EWI to the American Council enhances North America's involvement and role in the IIW and strengthens its representation of the welding industry internationally.

The IIW is made up of nearly fifty member countries and provides a global forum for the exchange of information related to welding technologies and applications. The objectives of the American Council are to serve the United States welding industry and related joining technologies, with a focus on the advancement of welding research and technology, standards, codes and procedures. The Council is also responsible for the promotion and development of international welding standards that reflect the interests of the United States. The official signing of EWI's induction took place at the 2006 Fabtech International & AWS Welding Show at the Georgia World Congress Center in Atlanta.

"As a leading engineering and technology organization dedicated to welding and materials joining, we believe we will be an asset to this important council, and are looking forward to collaborating with these distinguished associations to continue to advance the international presence of the United States welding industry," said EWI President Dr. Henry J. Cialone. "We take great pride in our involvement in the highly-respected IIW and are very enthusiastic about the opportunity to make continued contributions to the international materials joining industry."

About AWS:
The American Welding Society (AWS) was founded in 1919 as a multifaceted, nonprofit organization with a mission to advance the science, technology and application of welding and allied joining and cutting processes, including brazing, soldering, and thermal spraying. Headquartered in Miami, Florida, and led by a volunteer organization of officers and directors, AWS serves nearly 50,000 members worldwide and is composed of 22 Districts with more than 200 local Sections. Visit **http://www.aws.org** and click on "pressroom."

About WRC:
The Welding Research Council (WRC) was founded in 1935 as a not-for-profit association. Its members are comprised of science and engineering specialists who are committed to improving joining and pressure vessel technology and provide a forum for the exchange, evaluation, and dissemination of pertinent technical information. More than 1000 WRC projects, programs, and studies have been aimed at improving joining materials, design concepts, processes and procedures, inspection methods, codes, standards, and specifications. WRC publications concentrate on welding and pressure vessel research and provide specific recommendations based on validated technology. Visit **http://www.forengineers.org.**

About IIW:
Founded in 1948 as a non-profit organization, the International Institute of Welding (IIW) was created by a group of scientists and researchers to promote innovation and best joining practices. With nearly fifty member countries today, the Institute provides a global platform for the exchange and diffusion of evolving welding technologies and applications. The organization is driven by the combined synergy of thousands of experts who conduct and participate in IIW technical meetings, international congresses, assemblies and themed conferences. They also contribute articles and publications to share and compare their latest findings and actively further excellence in our field. Visit **http://www.iiw-iis.org**.

New EWI Members

CF Industries
Donaldsonville, LA
Business: Manufacturer of nitrogen and phosphate fertilizers

Corning Inc. MTE Process Engineering
Corning, NY
Business: Manufacturer of glass panels for plasma/hd tv's and projectors

Dometic Sanitation
Big Prairie, OH
Business: Manufacturer of marine and recreation vehicle sanitation systems

InnerPulse, Inc.
Research Triangle Park, NC
Business: Manufacturer of intravascular implantable defibrillators

Kiewit Offshore Services, LTD
Ingleside, TX
Business: Construction of offshore oil and gas structures and large structural steel components

Propel Industries LTD
Columbus, OH
Business: Holding company with operations (mfg/sales) in Atlanta, GA/ Belgium (SkyClimber) and Delaware, OH (VP Hydraulic Products)

Secat, Inc.
Lexington, KY
Business: Research and development for the aluminum industry

Weatherford Canada Partnership (COROD)
Edmonton, AB CANADA
Business: Oilfield equipment – continuous sucker rods

Welding Alloys (USA) Inc.
Florence, KY
Business: Manufacturer of tubular flux-cored welding wire for hard-facing and fabrication

Wolf Robotics
Fort Collins, CO
Business: Custom robotic welding solutions

EWI Facilitates Implementation of Electronic Welding Data Management System at Rock Island Arsenal Joint Manufacturing and Technology Center

EWI has recently facilitated the deployment of an electronic welding data management system called WeldEye™ at Rock Island Arsenal Joint Manufacturing and Technology Center (RIA JMTC) under the U.S. Army ARDEC Research, Development and Engineering Center (ARDEC) funded program called Advanced Welding Technology Deployment Initiative (AWTDI). WeldEye™ is a web-based software application capable of complete documentation of welding procedures, personnel qualifications, quality inspections, and management of welded fabrications by creating full electronic traceability. It has been developed by Weldindustry, Stord, Norway.

The AWTDI focuses on producing lightweight prototype structures to support U.S. Army weapons systems development. As a part of this initiative, EWI was asked to work with RIA JMTC to identify a tool to manage (arc) welding procedure specifications (WPSs) supporting the manufacturing of M119 howitzers (M119). Although a number of such commercial tools are available, the customizability and web-accessibility of WeldEye™ made it particularly appealing. The software package is also utilized by defense contractor General Dynamics Electric Boat (GDEB) for tracking WPSs. GDEB makes approved versions of procedures available to all trade skills and staff for reference at all of their facilities including Quonset Point (Rhode Island), Norfolk (Virginia), and Puget Sound (Washington).

After an in-depth training program and pilot testing of WeldEye™, EWI deployed the software at RIA JMTC (internally). With assistance from EWI, the RIA JMTC thoroughly evaluated WeldEye™ and selected it as their weld data management software package. As of the date of this article, RIA had inputted 600-700 multi-page WPSs into WeldEye™ and released approved versions for M119 production. In February 2006, the Prototype Manufacturing Team at Picatinny Arsenal (PICA) began using WeldEye™ through a remote, secure access to EWI's installation of the software. PICA is interested in tracking gas metal arc welding (GMAW) procedures for fabrication of titanium structures in support of the Future Combat System Program. EWI continues to provide engineering support to RIA JMTC & PICA under the AWTDI program.

The primary benefits of using the WeldEye™ welding procedures module are: **(a)** Simultaneous access to data for multiple users through an intra- or internet, **(b)** Producing, publishing, and issuing new welding procedures efficiently (nearly 80% faster), **(c)** Ease of revising, publishing, and re-issuing existing procedures (nearly 95% faster), **(d)** Reduced cost and risk associated with the loss of hardcopies of welding procedures or qualification data, **(e)** A means of searching the database for combinations of qualification data that might support the development of a procedure without additional qualification testing, **(f)** Customizability of welding procedure templates to meet both commercial and US military welding standards, and (g) Quality benefits with regards to compliance and audit.

Soldiers from the 7th Field Artillery Regiment, 25th Infantry Division (Light), position an M119 Howitzer near Forward Operating Base Cobra during Operation Crackdown in Afghanistan.

For information on other capabilities of WeldEye, contact Candice Mehmetli at 614.688.5180 or candice_mehmetli@ewi.org or Suhas P. Vaze at 614.688.5127 or suhas_vaze@ewi.org.

Insights

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Upcoming EWI Tradeshows & Presentations

Dates	Event	Host	Location	Web Site
2/21-2/22/07	Friction Stir Welding Technology for Defense Applications Workshops	NJC	Columbus, OH	http://www.ewi.org/NJC/
4/17-4/19/07	MRO Maintenance, Repair & Overhaul	Aviation Week	Atlanta, GA	http://www.aviationnow.com/conferences/mromain.htm
5/8-5/9/07	Materials Joining: Building for the Manufacturing Future	EWI	Columbus, OH	www.ewi.org