WELDING Journal

FEBRUARY 2016

AWS

- Joining Aluminum in a New Way
- Vacuum Brazing Techniques
- The American Welder: Daredevil Welder
- Liquation Cracking in Magnesium Alloys

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

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On the cover: A Dynamic Fabrication journeyman gas tungsten arc welds aluminum aircraft spacers. (Courtesy of Dynamic Fabrication, Inc., Santa Ana, Calif.)

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Planting the Seeds of Our Future

John Bray
AWS Vice President

During a past American Welding Society (AWS) board meeting, there was a discussion about our Sections being the "grassroots of our Society." This was stated by incoming District 10 Director Mike Sherman.

At the time, I did not really think about the truth in that statement. However, remembering back to when I served on the board of my local Houston Section for twelve years made me realize that was the "grassroots" of my AWS career.

Many of the volunteers who serve on our committees, subcommittees, and the national AWS board of directors came up through the Sections. That made me wonder how so many people were first introduced to AWS.

Our members attend local Section meetings and are able to meet and network with other members of our Society to exchange ideas and concepts. But how do members find their local Section meeting time and location?

All you have to do is go to the AWS website at *aws.org*. Click on "About" in the upper-right corner of the headings. This will bring up a screen that shows "Sections" at the box on the right-hand side. Then click on that and you will be taken to a screen that has "Find a Section" in the box on the right. Click on that, and it will take you to the listing of all the Sections' names in alphabetical order along with what city they are located in. Then click on the Section name you want, and the next screen gives you a picture of that Section's District Director along with all of his or her information and a listing of contacts for each Section.

Most Sections have websites that you can click on to get all of their meeting information and contacts. Some even give you pictures of past and future meetings along with speakers and events. It is all designed by AWS to help you get the information you need to contact with the local Sections and Districts around the United States, and it only takes a few seconds.

Information is critical to keep our "grassroots" fed and nurtured so we can grow our membership. It can make you stop and think about the fact that someone you met at a local Section meeting might be the next AWS president, and they don't even know it yet. As members of the Society, we have such a great opportunity to help grow new members.

How we plant that seed of excitement in someone to attend the local Section meeting is very important. With the younger generation so in tune with technology and social media connections, this has to be our best path to maintain their interest and desire to join AWS.

The staff at AWS is doing just that right now with maintaining the following websites and accounts:

- AWS WeldLink, *awsweldlink.org*
- Jobs In Welding, *jobsinwelding.com*
- Careers In Welding, *careersinwelding. com*
- Facebook, *facebook.com/AmericanWeldingSociety*
- Twitter, *@AWSHQ*
- Instagram, *americanweldingsociety*.

We need to discuss that information about our new features at every meeting.

So, still the question comes back to how do we grow those seeds into the roots of our Society? In particular, how can we reach out and develop in the next generation of men and women an interest in the welding profession as an honorable way of life?

Senator Marco Rubio said, "Welders make more money than philosophers," and we have to do a better job of getting the message to people that you can make a very good living by being a welder. Then the next step is to show all of the different avenues you can take in your welding career.

So with all of our new "AWS tools," it is our job as members to get the word out of how valuable being involved in your local Section really is. It goes back to being an "AWS mentor." The most important asset we have is "people."

When speaking at different engagements about AWS, I am always amazed at how 138 AWS staff members maintain, serve, and assist more than 72,000 members worldwide.

With the help of our staff and volunteers, the sky is the limit for what we can accomplish with growing our seeds for the future of welding and AWS. WJ

"How we plant that seed of excitement in someone to attend the local Section meeting is very important. With the younger generation so in tune with technology and social media connections, this has to be our best path to maintain their interest and desire to join AWS."

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Low-Energy Impact Spot Welding of High-Strength Aluminum Alloys

The results of impact welding of aluminum Alloys A5052 and A7075 performed with the recently developed vaporizing foil actuator welding technique are reported

Conventional welding by means of high heat input, fusion, and solidification greatly alters the microstructure in the welded region and can be detrimental to the weld's mechanical properties, especially in the case of highly engineered, high strength-to-weight ratio materials. The strength of the heat-affected zone (HAZ) can be reduced to as little as one third the original strength of the base material. Additionally, susceptibility to corrosion is greatly increased after welding certain alloys such as 6xxx and 7xxx series aluminum alloys. Fasteners and structural adhesives offer nonwelding joining solutions. Solid-state welding techniques, such as impact welding, friction stir welding, ultrasonic welding, and roll bonding are some alternatives to fusion-based welding and have undergone a certain degree of industrial adoption so far. Impact welding is of particular interest due to the potentially short cycle time of the process, the possibility to join a wide variety of metal combinations, and the ability to perform the process over varying length scales.

Vaporizing foil actuator welding (VFAW) is a novel impact welding technique that utilizes the force generated by a thin aluminum foil vaporized by high electric current to launch one piece of metal toward one or more stationary target sheets (Ref. 1). At high speed, oblique impact between the flyer sheet and target plate(s) leads to scouring of the colliding surfaces and subsequent bonding under high pressure — Fig. 1. Explosive welding (EXW) and magnetic pulse welding (MPW) are previously known and practiced methods of impact welding. Implementation of EXW in a traditional factory environment is not possible due to safety regulations in transportation, storage, and handling of explosives, and because of the inability to automate such a process. Explosion welding is mostly used for welding thick plates for the shipbuilding, nuclear, oil and gas, and locomotive industries. Vaporizing foil actuator welding currently operates at the same size scale as MPW while having certain advantages over it. Longevity of the solenoid actuator used for MPW is a major concern, whereas VFAW is designed to have a low-cost consumable for each cycle. With VFAW, generated pressures and achievable flyer sheet velocities are much higher as compared to MPW; therefore, a wider variety of materials can be effectively welded with VFAW.

This article illustrates VFAW of aluminum Alloys A5052 and A7075. This

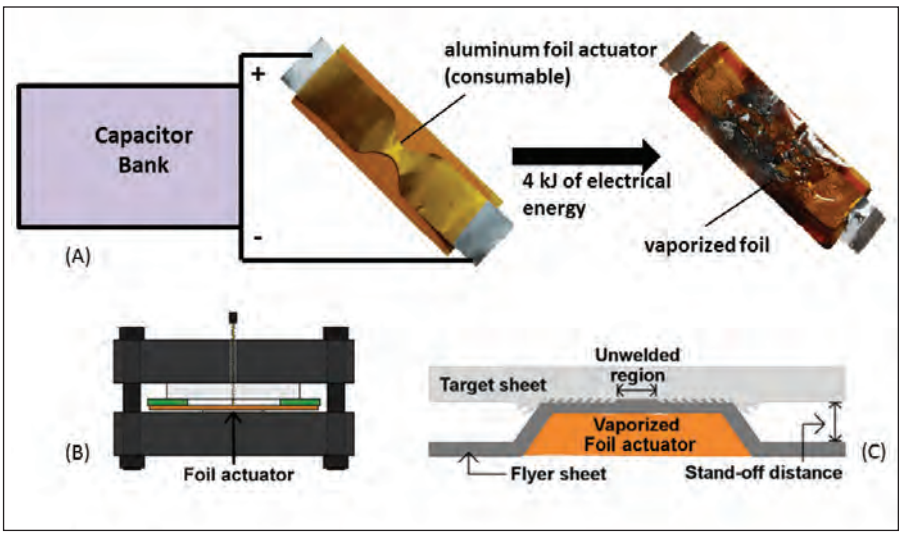

Fig. 1 — Schematics of the VFAW process. A — Before and after experiment conditions of the foil actuator; B — stackup of a typical VFAW assembly; C — closeup of the welding operation.

BY ANUPAM VIVEK, SCOTT M. WRIGHT, TAESEON LEE, GEOFFREY A. TABER, AND GLENN S. DAEHN

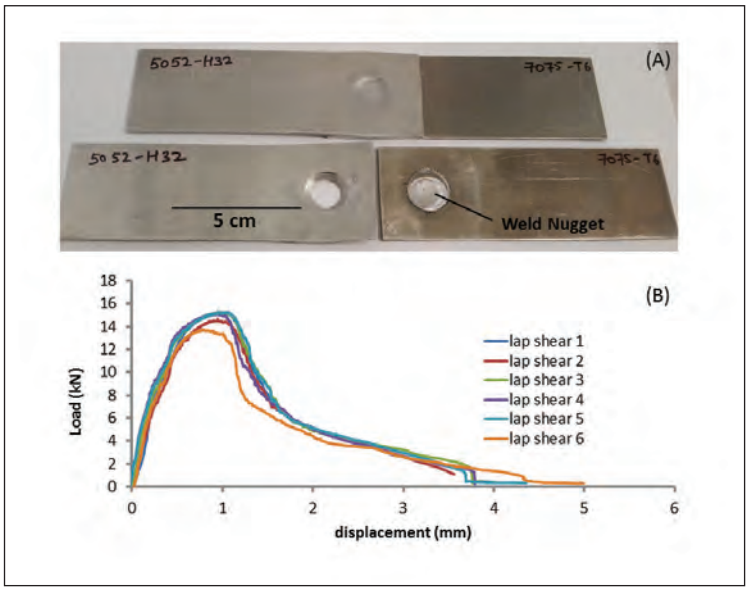

Fig. 2 — A — A5052/A7075 VFAW spot welded samples before and after lap shear testing; B — a plot showing variation in load with stroke during lap shear testing of the welded samples.

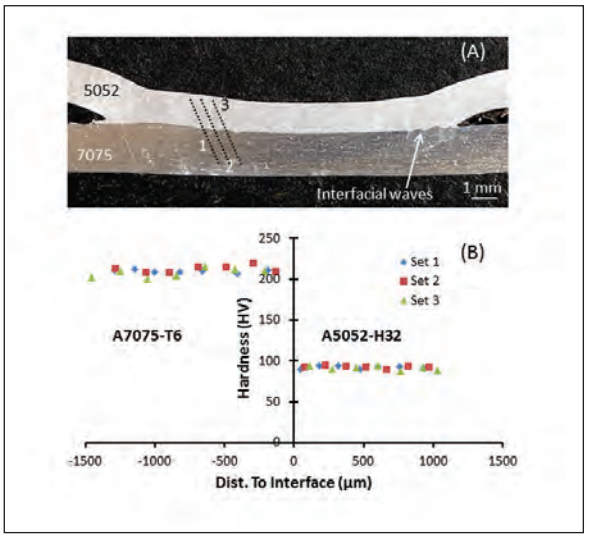

Fig. 3 — A — Cross-section image of the welded sample depicting the lines along which microhardness testing was performed; B — test data showing constant microhardness on either side of the weld interface.

material combination is germane to the effort in the automotive industry toward vehicle weight reduction. While 5xxx-series aluminum alloys are increasingly being applied for inner components of automotive structural assembly, 7xxx-series alloys have been scarcely utilized. This is despite the superior mechanical properties offered by 7xxx-series alloys as compared to 6xxx and 5xxx-series alloys. Forming and joining are considered two major barriers to the widespread implementation of 7xxx-series alloy as a lightweight alternative. Although there are certain drawbacks with the method, it is possible to use hot stamping to form 7xxx series into components such as B-pillar outers (Ref. 2). In this work, VFAW will be presented as a promising technique for solving the joining problem.

Experimental Procedure, Results, and Discussion

A 0.0762-mm-thick aluminum foil, with a shape as shown in Fig. 1, was connected across the terminals of a Maxwell-Magneform capacitor bank, which has a short circuit current rise time of 12 µs. While the capacitor bank can be charged up to 16 kJ, for these experiments it was operated at a 4-kJ energy level. Once this energy was discharged through the foil, the latter vaporized rapidly and formed a high temperature gas that can push on the 2-mm-thick A5052-H32 flyer sheet. Some degree of confinement is essential; accordingly, the other side of the foil was backed by a block of steel approximately 2 cm thick. The flyer sheet was separated from the 2.3-mm-thick A7075-T6 target plate by a 2.5-mm-thick neoprene washer with an inside diameter of 19 mm and outside diameter of 37 mm. The target plate was backed by another block of steel about 2 cm thick. The in-plane dimensions of the flyer as well as the target plates were 40 mm ¥ 120 mm. The two were overlapped by 40 mm along the length and the welding experiment was conducted to create lap-joint specimens. Due to the low strength of the neoprene washer, it breaks and gets ejected from between the flyer sheet and target plate. Six welded samples were created this way and subjected to lap shear testing, microhardness testing, and imaging.

In a separate experiment, the velocity of the flyer sheet was measured using a device called the photonic Doppler velocimeter (Ref. 3). In this experiment, the target plate had a through hole, which provided a line of sight to the laser focusing probe. With this technique, the evolution of the flyer sheet velocity can be measured with a submicrosecond temporal resolution. Voltage was measured using a 1000:1 probe connected across the terminals of the capacitor bank, and current was measured by a 50-kA:1-V Rogowski coil.

Figure 2A shows an impact spot welded specimen before and after lap shear testing. The load vs. displacement data for each sample is plotted in Fig. 2B. The samples failed outside the weld nugget at an average load of 14.5 kN. The average nugget diameter was 10 mm. As compared to friction spot welds and resistance spot welds between similar materials, the welds created by VFAW are roughly twice as strong. This can be attributed to three factors: 1) negligible thinning around the welded area, 2) no HAZ, and 3) very effective metallurgical joining at the bond line. The weld cross-section image in Fig. 3A depicts the characteristic wavy morphology of an impact welded interface in some parts of the weld. The figure also shows the flyer sheet retained its original thickness in and around the weld. The microhardness data (Fig. 3B) also reveals that the Vicker's hardness on both sides of the weld interface and around the weld nugget was held constant at the base material level, which is 90 HV for A5052 and 205 HV for A7075. This is due to the low external input energy to the weld. It turns out that the input energy for VFAW is not only an order of magnitude smaller than that for resistance spot welding, but is also merely a fraction of the energy required for friction spot welding or self-pierced riveting processes (Ref. 4).

Diagnostics show the impact velocity was 770 m/s and the peak current was 100 kA. Based on rough estimates on the mass of the circular flyer sheet, the conversion efficiency from electrical to kinetic energy in launching the flyer sheet can be estimated as 5%. Other impact welding techniques such as MPW and EXW tend to offer less than 1% energy efficiency.

Various combinations of materials including steel, aluminum, magnesium, titanium, copper, bulk metallic glass, niobium, nickel, and tungsten have been successfully welded using VFAW, and many of these studies and examples are provided on a website dedicated to these impulse technologies (*iml.osu.edu*). Therefore, VFAW has wide potential application not only in automotive, but also in aviation, appliances, and power generation industries. However, like any early-stage lab-based technology, much development work is required before the technique is commercialized. The research group at The Ohio State University has recognized the following three main areas for improvement and is actively working on them:

1. **Automation**: The present welding apparatus is a manually assembled bench prototype. The placement, energization, and removal of the foil actuator need to be automated to minimize system downtime and increase reproducibility.

2. **Fixturing**: As seen in Fig. 2B, there is variation in the failure loads, which is primarily due to variation in the nugget size. More robust and reproducible fixturing can mitigate this issue. Furthermore, the welding fixture will need to be adapted to accommodate industrial components and not just flat coupons.

3. **Noise reduction and handling of fumes**: With a polycarbonate box around the work area, the noise level from a vaporization event was measured as 105 decibels. This is near the upper safe operating limit in a typical factory setting. Beside, the gaseous products of each shot need to be collected and properly disposed of for an industrial operation.

Conclusions

In this work, A5052 and A7075 sheets were welded with 4-kJ input energy for each weld. The average failure load was 14.5 kN and all the samples failed in the base A5052 material. The energy requirement for VFAW is significantly lower than that for resistance spot welding of aluminum alloys. With minimal process-induced changes in geometric and mechanical properties of the base materials, VFAW enables almost 100% joint efficiency, which sets it apart from other available joining techniques. Although significant effort is required for full-scale industrial implementation of this technology, early signs show that VFAW can play an important role in the world of joining. WJ

Acknowledgments

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Fabricating without Fear

Artist, rock-climber, and welder Jamie Hamilton fabricates his own tightrope supports

BY VIRGINIA HILTON

Jamie Hamilton walks on the aerial installation, Amor Fati (2015, steel, aluminum, nylon, neoprene, 70 x 260 x 150 ft), located outside of Santa Fe, N.Mex. Photo courtesy of Hannah Hughes.

How confident are you in your work? Would you bet your life on it? That's what aerial artist and welder Jamie Hamilton does every single day. He builds the support structures for tight ropes that are several hundred feet above the ground, which he then walks across. He also makes the safety nets that catch him in case he falls.

For most people, the height alone would be blindingly intimidating, but Hamilton has been rock climbing since he was eight years old. Since then, he's climbed summits in the Himalayas, Alps, Canadian Rockies, and Yosemite.

He started learning about welding and fabrication in high school. Hamilton said he enjoyed building with metal. "I was fascinated by this material that could become liquid, but was also strong and ductile. I fell in love with the material and the forgery of it."

He built many practical structures

Fig. 1 — Image from a solo show at The Center for Contemporary Arts, Santa Fe, N.Mex. Photo courtesy of Nick Merrick, Hedrich Blessing.

while working as an apprentice for an architectural blacksmith and found that most of them were like works of art. "When structures become totally pragmatic, like a bridge, they become beautiful. They're not designed to be that way, but in their purpose they have a sense of artistry and grace," he said.

That beauty motivated him to continue his fabrication work, but with an eye toward the arts. He studied sculpture at Bard College in New York and recently graduated with a masters in fine arts from Transart University in Germany — Fig. 1.

Once in his 30s, he decided he wanted to find a way to combine all three of his passions: athletics, fabricating, and art. Soon after, he started working on his first tightrope. "An exploration of possibility and structure has always been a staple in my work, but it becomes much more serious when building aerial structures upon which my life depends. I take a stance of total responsibility when I become engineer, designer, fabricator, and performer," he explained.

The first thing he does before each project is think about the scale of the build. "I try to figure out how tall it's going to be. How will it be supported or installed? Will it be across a gorge, natural setting, or supported by trusses?" — Fig. 2.

Once he determines which support system he is using, Hamilton heads to his shop in Santa Fe to begin fabrication. "I have to start engineering the dimensions and determine what will be needed to support the load," he explained. In the example of a self-supporting rig, he essentially makes two columns, anchored to the ground, that are supported by lattice trusses that support each end of the tightrope.

Hamilton uses a Hypertherm Powermax85 plasma cutting machine to build many of the customized steel components that are anywhere from ¼ to 1 in. thick. "When building a steel structure like this, you can't go to a

Fig. 2 — High-wire crossing a canyon outside of Santa Fe, N.Mex. Photo courtesy of Charles Calef.

Fig. 3 — Gas tungsten arc welding a component for a sculpture. Photo courtesy of James Autery.

hardware store to buy the parts. I design and build many of them myself with a handheld torch and various cutting jigs," he said. His aerial structures and sculptures are almost exclusively gas tungsten arc welded. He uses a Miller Dynasty 350 as his primary welding machine. If Hamilton has to make a field or in-situ weld, he will use shielded metal arc welding, but this is very rare as almost all of his field connections are made with bolts and pins. The vast majority of his welding and fabrication takes place in the shop.

In the past, he used grinders with cutting disks to do some of the work but found switching from abrasive to plasma saved him hours of cutting time and money. He also said he felt plasma was a safer option because there wasn't as much metal or grit debris produced during each cut.

Once he has everything cut and shaped, he welds the components of the truss sections, which will become the high wire's support columns — Fig. 3. The columns are built to sleeve together at the joints. "When I'm erecting them, I lay them out, bolt them together, then the hinges at the base allow them to pivot upright via a winch and jin pole," he explained.

Just above the ground he weaves his own safety net made of thousands of sliced nylon ropes. The process can take several months to complete.

Each time he takes the first step,

Fig. 4 — Portrait of Jamie Hamilton, courtesy of Ben Gilkison, The Needles, Calif.

Hamilton said he tries to remain calm. "While it seems totally crazy, even though I am trying hard to focus, sometimes my mind wanders, and I actually think about mundane things like the bills I need to pay."

Knowing that he made the structure gives him the confidence and composure he needs to make it across. "It gives me a sense of security knowing that I built it myself. I have nobody else to blame if something goes wrong," said Hamilton — Fig. 4. That mentality has carried over into other parts of his life as well. "Real self-responsibility. I don't wish to blame anyone else for things that go wrong in my life. That has been a great lesson from this."

For more information about Jamie Hamilton's work, contact him at *arecibo@c1h2.net*. WJ

VIRGINIA HILTON is a freelance writer.

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