Celebrating Ten Decades of Welding Research

Before and since the advent of the* Welding Journal *Research Supplement, AWS has published important welding-related research

American Welding Society®
CELEBRATING 100 YEARS
SINCE 1919

Adding to the body of knowledge about welding has been integral to the American Welding Society (AWS) since its inception. In fact, the Society's stated mission, which is printed on the cover of every issue of the *Welding Journal*, is to "advance the science, technology, and application of welding and allied joining and cutting processes worldwide, including brazing, soldering, and thermal spraying." To that end, every paper published in the *Welding Journal* Research Supplement since 1970 is available for download in PDF format on the AWS website at *aws.org/publications/page/research-papers*.

The First Fifty Years

The *Welding Journal* Research Supplement came into being in 1937, but that certainly didn't mean welding research wasn't being published in the *Welding Journal* prior to that time. The following are just a few of the important papers published during the Society's first 50 years. (Much of the information for this section was drawn from the article The *Welding Journal* — Six Decades of Reporting, by former *Welding Journal* Editor Ted Schoonmaker.)

X-ray Tests of Welds by P. W. Swain, June 1926, 5(6): 50–58. A pioneering paper on the use of x-rays to detect hidden defects — Fig. 1.

Cutting Metals Under Water by L. F. Hagglund, May 1927, 6(5): 51–54. "This method combines the heat of the electric arc, together with the oxidizing effect of a stream of gaseous oxygen. The electric arc can be drawn under-water as well as on the surface, and the electric circuit is similar to that used in electric welding. A hollow carbon electrode is used and the oxygen forced through this electrode under pressure is directed onto molten metal where the arc is acting. The oxygen serves two purposes. It completely oxidizes part of the metal, and in addition it tends to blow molten metal out of the cut, thereby preventing the rapid solidification of the metal as such due to the cooling effect of surrounding water."

Electroslag Welding of Very Thick Material by B. E. Paton, December 1962, 41(12): 1115–1123. The first paper from the USSR on electroslag welding. The author was the son of E. O. Paton, for whom the famous E. O. Paton Welding Institute in Kiev is named. E. O. Paton had published a paper titled **Impact Load Tests on Arc Welded and Riveted Beams** in the June 1931 issue.

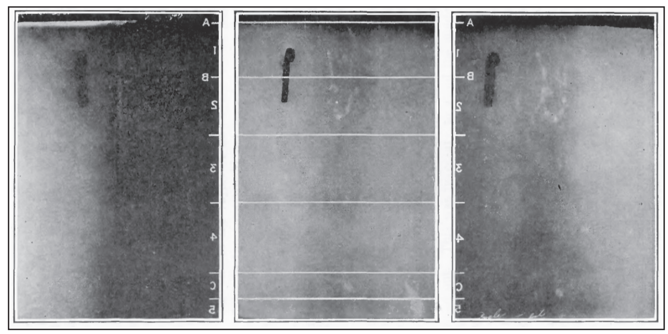

Fig. 1 — Images of some of the first use of x-rays to detect weld discontinuities and defects.

Single-Pass Electric Welding of Unfired Pressure Vessels by R. M. Wallace, January 1939, 18(1): 17–26. The first detailed article on submerged arc welding published in the *Welding Journal*. In this article, the process was referred to as "Unionmelt" welding. "The future should show even greater possibilities in its application to alloys used for heat exchanger service subject to high temperatures, high pressures, and severe corrosion."

Effect of Welding on Ductility and Notch Sensitivity of Some Ship Steels by R. D. Stout, L. J. McGeady, C. P. Sun, and G. E. Doan. June 1947, 26(6): 335-s to 357-s. Detailed the Lehigh restraint cracking test and its application.

High-Strength Vacuum Brazing of Clad Steels by R. C. Bertossa, October 1962, 31(10): 441-s to 447-s. "A system of vacuum brazing has now been developed wherein sound and continuous high-strength bonds can readily be obtained throughout areas of virtually unlimited size without the use of introduced furnace atmospheres and without contamination from fluxes."

The Second Fifty Years

Nowadays, it's easier to find the research that most resonates with other researchers because we can find which are the most cited papers on the Web of Science. Surprisingly, the two most-cited papers over the past 50 years did not appear in the *Welding Journal* Research Supplement, but in the features section of the magazine.

The first is **Friction Stir Process Welds Aluminum Alloys** by C. J. Dawes and W. M. Thomas on pages 41–45 of

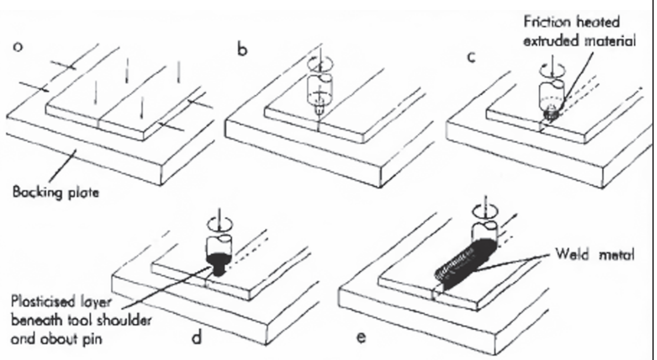

Fig. 2 — Schematic of the friction stir welding operation. A — The parts to be joined are clamped to a backing plate; B — a cylindrical-shouldered tool with a special pin profile is positioned with its axis on the joint centerline; C — the tool is rotated at a certain peripheral velocity and plunged into the joint; D — plasticized metal, through friction heating, is removed until the tool shoulder is in intimate contact with the work surface; E — when the tool is moved against the work, or vice versa, plasticized material is moved from the front to the back of the pin thus forming a weld on consolidation as the pin, and the heat source, move away.

the March 1996 issue — Fig. 2. Dawes and Thomas, both then principal research engineers, Electron Beam, Friction and Forge Processes Department, TWI, Abington, Cambridge, UK, wrote: "Friction stir welding is a remarkable new welding technique for joining aluminum alloys and has the potential for welding other higher-melting-point materials. Although still an infant welding process, it has already been developed beyond a laboratory curiosity and has been proved as a potential practical welding technique offering low-distortion, high-quality, low-cost welds from simple concept machine tool welding equipment. Several industrial companies are conducting pilot studies for using friction stir welding in production.

"Designers, welding and production engineers considering welded fabrications involving aluminum alloys are advised to consider this welding technique." This feature article describing the process has since been followed by numerous scholarly papers published in the *Welding Journal* Research Supplement.

The second highest-cited paper is **TLP Bonding: A New Method for Joining Heat-Resistant Alloys** by D. S. Duvall, W. A. Owczarski, and D. F. Paulonis, which ran in the April 1974 issue on pages 203–214. In the introduction, the authors wrote: "TLP bonding is a new process now in production which economically produces high strength diffusion bonds in heat-resistant materials without the need to apply substantial pressure during bonding. The process uses a mating surface interlayer alloy which temporarily melts and then resolidifies at the bond temperature to form a joint whose characteristics resemble those of a solid-state diffusion bond. With this bonding method, joints can be made in complex shaped parts using simple tooling and mating surface preparation. Bonding is conducted in conventional vacuum or argon atmosphere heat treating furnaces so that large numbers of parts can be bonded in each process cycle."

The top five papers that ran in the research supplement are as follows:

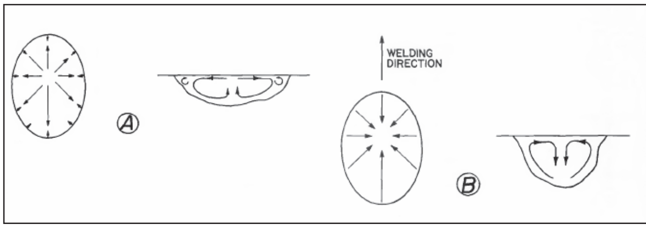

Fig. 3 — Apparent fluid flow pattern on weld pool surface and proposed subsurface flow pattern: A — High-aluminum welds; B — high-sulfur welds.

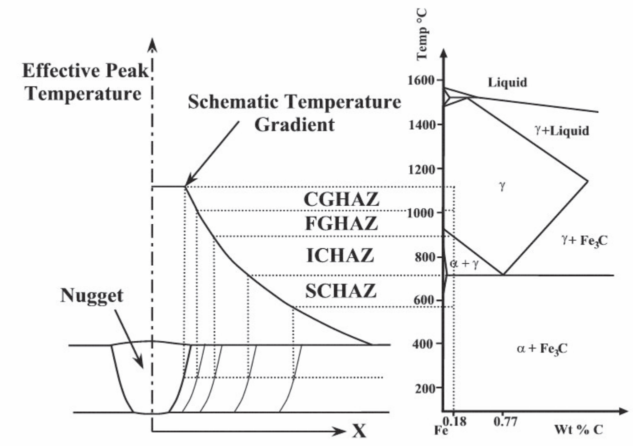

Fig. 4 — Schematic illustration of the different regions of the HAZ of a friction stir weld on mild steel and their relation to effective temperatures in the Fe-Fe_3C binary system.

Mechanism for Minor Element Effect on GTA Fusion Zone Geometry by C. R. Heiple and J. R. Roper, April 1982, 61(4): 97-s to 102-s. Surface-active impurities altered surface tension gradients in the molten weld pool, thereby changing fluid flow patterns and fusion zone geometry — Fig. 3.

Material Flow Behavior during Friction Stir Welding of Aluminum by K. Colligan, July 1999, 78(7): 229-s to 237-s. Tracers embedded in the weld path and a "stop action" technique gave insight into the movement of material during friction stir welding.

Weld Pool Development during GTA and Laser-Beam Welding of Type-304 Stainless Steel, Part 1: Theoretical Analysis by T. Zacharia, S. A. David, J. M. Vitek, and T. DebRoy, December 1989, 68(12): 499-s to 509-s. The analysis revealed the realistic influence of surface-active elements and temperature distribution on penetration.

Friction Stir Welding Studies on Mild Steel by T. J. Lienert, W. L. Stellwag, B. B. Grimmett, and R. W. Warke, January 2003, 82(1): 1-s to 9-s. Process results, microstructures, and mechanical properties were reported — Fig. 4. Results demonstrated the feasibility of FSW of steel without loss of tensile properties. Based on these results, FSW of transformation hardenable steels, HSLA steels, and stainless steels may be feasible.

WRC-1992 Constitution Diagram for Stainless Steel Weld Metals — A Modification of the WRC 1988 Diagram by D. J. Kotecki and T. A. Siewert, May 1992, 71(5): 171-s to 178-s. This refined constitution diagram offered a more accurate FN prediction for Cu-containing stainless steels and dissimilar metal joints. WJ