

Impact of Digital Technology on Stud Welding

Stud welding advances from the analog world to the digital

Historians estimate that humans have been experimenting with and perfecting welding techniques for more than 5000 years. In the ancient world, the mastery of welding and other forms of metalworking was equated with success in the marketplace, even political power.

While its importance in the marketplace did not change much over the centuries, the welding process did. In the 1940s, a welder with a covered electrode, like many welders before him, stuck his electrode into a weld pool, but this time the welder had the idea of putting threads onto the electrode — and stud welding was born.

During the 1940s, the immediate application of stud welding was for the Navy to help install wood decking onto naval vessels. During WWII, this helped to vastly speed up production of ships for the U.S. Navy. The method was crude with the operators controlling the arc timing with their thumbs, but it was vastly superior to welding the deck retention fasteners by hand.

Since this initial application of stud welding, it has continued to evolve.

The Stud Welding Process

In the stud welding process, a metal

stud is joined to a metal workpiece by heating both parts with an arc. Unlike other fastening processes, stud welding attaches the fastener to the workpiece without marring or requiring access to the other side. The benefits to this type of welding include the following:

- A strong weld that will not break, loosen, or weaken
- Faster, easier assembly with greater productivity
- Single-sided fastening
- Increased cosmetic appeal without marring the other side
- Fewer manufacturing steps saves time and money
- Greater design freedom.

Going Digital

During the 1990s, a major stud welding company, based in northwestern Chicago, designed and developed the first digital welding equipment, significantly changing the industry.

With the introduction of digital stud welding equipment into the marketplace, the industry has seen increases in productivity and reliability. Why is this? First

of all, digital stud welding equipment uses microprocessors and/or digital signal processing to monitor and control the weld profile in narrow time increments (milliseconds). In traditional analog power controllers, electrical component tolerance is such that typical systems need wider control limits to make the system economical. Much of the equipment delivers power to $\pm 20\%$ of the desired output.

With digital back-end control, analog functions have been converted into software; therefore, component tolerance is not a significant factor, and power is typically controlled to $\pm 2\%$ or better. This makes the welding process more consistent, repeatable, and predictable over time. Additionally, it is more economical to outfit digital controls with advanced features such as weld setup memory, weld counters, automatic profile adjustments, and multiple weld outputs.

The Drawn Arc Stud Welding Process

All of the above technological advances serve the unique needs of drawn arc stud welding. Drawn arc stud welding provides welding success under a broad range of conditions. Producing one-sided, full cross-sectional welds, the process

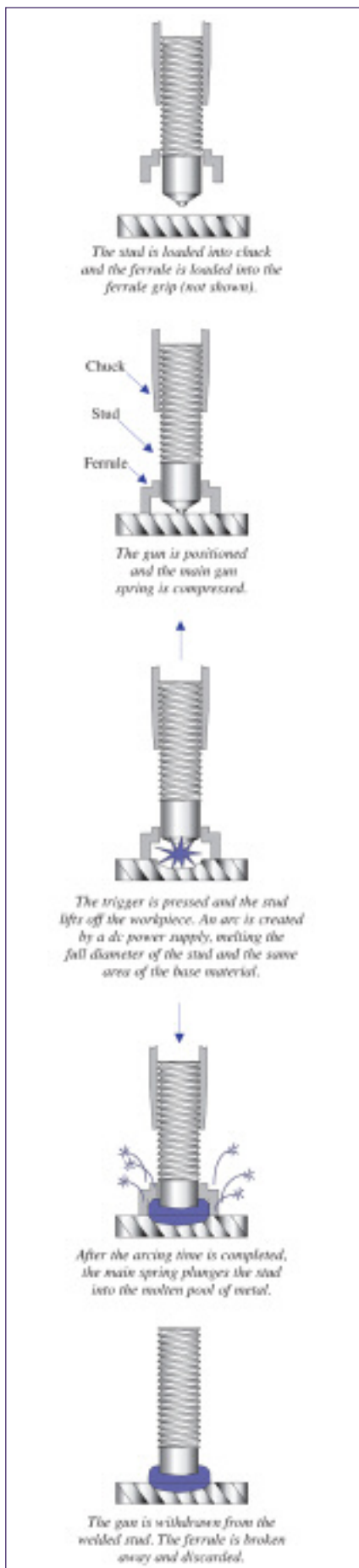


Fig. 1 — Main steps in drawn arc stud welding.

forms a weld that is stronger than the surrounding metal. Drawn arc welds offer structural integrity, productivity, and leak and corrosion resistance. They will not break, loosen, or weaken over time.

Drawn arc stud welding can produce welds in as little as 0.06 seconds for base metals of 0.048 in. (1.2 mm) or thicker. The process has good penetration, and it welds almost any size or configuration of metal stud to a workpiece.

The drawn arc process utilizes a DC power supply to create the arc, a stud welding tool, and metal fasteners. There are three common processes within drawn arc stud welding: flux and ferrule, short cycle arc, and gas arc.

Flux and Ferrule

In drawn arc stud welding, the stud is loaded into the stud gun chuck, and a ferrule (ceramic shield that encases the molten metal) is placed over the end. The gun is placed against the work position, and the trigger is pressed. The DC power supply sends a signal that energizes the weld tool's internal lift mechanism, lifting the stud and drawing a pilot arc. As the stud and base metal are joined, the metal begins to solidify and the weld is created. The gun is lifted and the ferrule is easily discarded.

Flux, embedded in the stud, cleanses the atmosphere during the weld. During arcing, the flux is vaporized and combines with the contaminating elements in the air to keep the weld zone clean at all times. A graphic representation of the drawn arc process is shown in Fig. 1.

Additional assembly steps in the process such as punching, drilling, tapping, and riveting are eliminated, making drawn arc stud welding even more efficient.

Short Cycle Arc Stud Welding

Short cycle arc stud welding uses no flux load or ferrule and offers the shortest welding times of all the drawn arc stud welding methods. While it's suitable for high-volume, lower-strength applications, it can produce porous welds and should be selected when speed and cost are a priority over strength.

Gas Arc Stud Welding

The gas arc method uses inert shielding gas with no flux or ferrule, making it easier to automate, but it provides less fillet control and less depth of penetration in comparison with the flux and ferrule process. In gas arc welding, a spark shield delivers the gas. The stud is loaded, and the gun is positioned for welding. When the user pulls the trigger, shielding gas

(preflow) floods the welding zone. The stud is lifted, and the arc is generated. While the stud remains lifted, the arc melts the stud and base metal. Once the arc time is complete, the stud is plunged into the molten pool. The gas continues to flow until the molten metal cools. The gun can then be removed. Since no ferrule is used, this process lends itself well to automation and robotics.

Drawn Arc Stud Welding Applications

Today, the drawn arc stud welding process has found extensive use in a wide variety of applications across an array of industries including the following:

- Automotive — heat shields, power steering, insulation, exhaust systems, lighting systems, hydraulic/brake/fluid lines, electrical wire routing, and trim
- Construction — bridges, buildings, conduit, and piping
- Farm equipment — fenders, brackets, cabs, spreaders, shrouding, thresher teeth, and wiring and hose management
- Highway equipment — cover plates, nonskid devices, wiring, and hose management
- Metal products — barbecue equipment, enclosures, heating/plumbing apparatus, insulation enclosures, HVAC units, and water storage systems
- Industrial — inspection cover plate attachments, enclosures, flow indicators, material handling equipment, and controls
- Power generation and distribution — power transformer tanks and transducers
- Shipbuilding — insulation, wire management, and hatch covers
- Electrical/electronic — electrical enclosures and hydraulic lines.

As valuable as digital innovations are to techniques like drawn arc stud welding, they've proven essential to processes that demand a high level of precision, such as capacitor discharge (CD) stud welding.

The Impact of Digital CD Stud Welding

Applying digital technology to CD welding has yielded several benefits. First, the voltage control is more precise. In other words, the

charge/discharge hysteresis window is smaller with digital controls. This means that the actual weld voltage is more accurate and repeatable.

Digital electronics control the charge profile more precisely via exacting phase control. This means that a larger capacity welding machine can be used with lower amperage building line supplies without tripping any circuit breakers.

Furthermore, in some applications, microprocessor control has allowed the heavy bulky transformer to be eliminated to achieve CD welding power supplies that weigh as little as 10.5 lb with ¼-in. fastener capability.

Most importantly, digital controls have enabled advanced operator safety. In analog systems with a shorted weld SCR, capacitor voltage can be present within the weld tool at any time, endangering the operator. The microprocessor in digital power supplies is able to actively monitor component health and deactivate the power supply completely in the event of critical component failures.

Capacitor Discharge Process Advances

As with drawn arc stud welding, technological advances in the capacitor discharge equipment have basically reinvented the process for lightweight applications. Capacitor discharge, or CD stud welding, is a popular option when appearance is a critical product feature. Using very short weld times, it permits the welding of small-diameter studs to thin, lightweight materials with very little distortion, discoloration, or burning. The weld cycle can be completed in 0.004 to 0.01 s on material as thin as 0.020 in. (0.5 mm). The fast weld times of CD help to minimize heat buildup. Additionally, it allows the welding of dissimilar metals because the weld penetration is so slight that it avoids metallurgical conflicts. Metals typically used in this process include mild steel, stainless steel, and aluminum, as well as brass, tungsten, and copper.

A CD welding system, using a capacitor storage system, delivers a rapid electrical discharge, stud welding tools, and fasteners. Ferrules and flux are not needed.

Two techniques used in the CD method are contact and gap. Both use a specially designed stud with a projection, or ignition tip, on its weld end. The stud tip provides accurate welding time control with repeatable precision.

The quality, productivity, and cost advantages of CD stud welding include

- Attractive appearance with minimal burn. Often important in cosmetic applications, CD stud welding offers appealing

one-sided welds with no reverse side dimples.

- Strength in lightweight applications. This method creates a strong, high-quality bond on very lightweight materials that would normally be compromised when using other fastening processes.

- Minimal backside marking. CD stud welding allows backsides to be pre-painted without damage to the paint.

Contact CD Stud Welding

During the contact method, the stud is loaded into the gun and positioned in contact with the workpiece. Energy is then discharged instantaneously from capacitors through the stud's projection. Since the size of the ignition tip cannot handle the current density of the capacitor's stored energy, it vaporizes, creating a gap that allows an arc to be formed. As the arc begins to melt the stud and workpiece, the two pieces are forced together, and a weld is produced in milliseconds as the metal cools.

Gap CD Stud Welding

The gap CD stud welding process offers very short weld times with higher current densities when compared with contact CD stud welding. With such quick welding capability, this technique is particularly well suited to cosmetic applications, since it produces very minimal backside marking.

While the contact CD process rests the stud on the workpiece, the stud for the gap process is positioned above it. When the stud is released, it accelerates toward the base metal. When the stud contacts the workpiece, the ignition tip is vaporized and the pieces are melted, then brought together to form the weld. Because the stud starts in motion, the weld times are even faster than those created in the contact process — approximately 0.004 s with peaks of 12,000–15,000 A.

Gap CD stud welding is ideal when welding aluminum or nonferrous alloys, which have an excellent ability to conduct heat. With slower techniques, the base material can draw heat away too fast for a weld to occur, but gap CD welding's fast weld times overcome this phenomenon. The stages of both gap and contact CD stud welding can be found in Fig. 2.

Capacitor Discharge Stud Welding Applications

Capacitor discharge stud welding creates high-integrity welds on the thinnest gauge of materials. Because it provides fast welds on lightweight

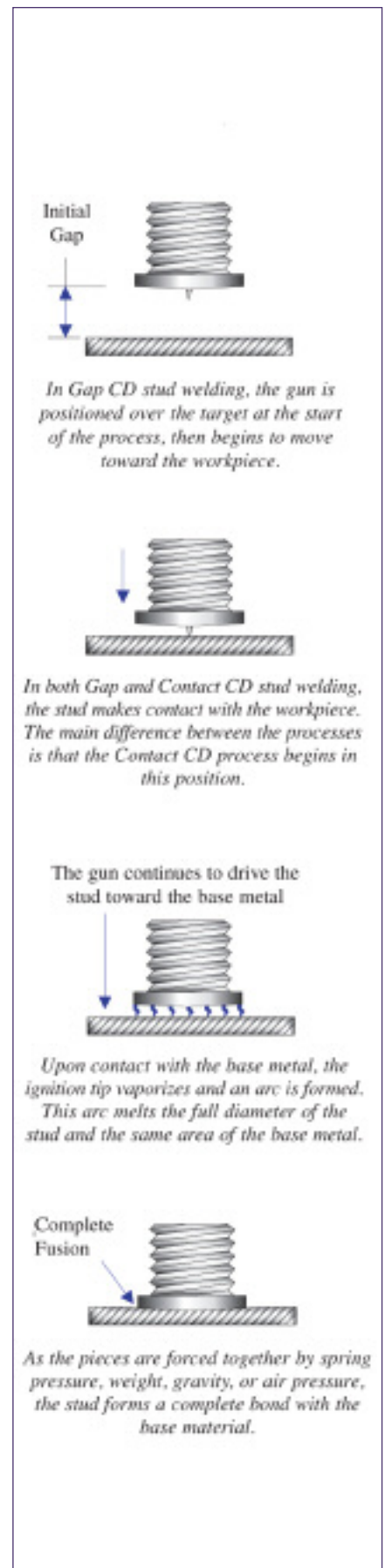


Fig. 2 — Various steps in gap and contact capacitor discharge stud welding.

Technological advances in the capacitor discharge equipment have basically reinvented the process for lightweight applications.

materials with minimal distortions, popular applications of the CD method include:

- Jewelry — earrings, pins
- Hardware — brackets, cleats, and tool handles
- Cookware — utensils, pots and pans, and handles
- Electrical housewares — electric frying pans, cookers, oven assemblies, and microwave guides
- Electrical/electronic — components, terminals, pumps, motors, communication equipment, and electronic systems
- Doors — commercial doors, es-cutcheon plates, and insulation.

The Future of Digital Stud Welding

Stud welding is a science and, like all sciences, continues to evolve. We can expect numerous improvements to refine the digital stud welding process. Welding tools will keep getting smaller, lighter, and more adaptable. The precision of welding equipment and the ease of sensor read-outs will increase with each new technological advancement. As a result, the process itself will become faster, easier, and more affordable, putting digital stud welding in the hands of more people and opening still more practical applications for stud welding. ♦