Portable and Intelligent Stud Welding Inverter for Automotive and Sheet Metal Fabrication

C. Hsu, D. Phillips, C. Champney and J. Mumaw
Nelson Stud Welding, Inc.

ABSTRACT

This paper introduces a new, portable and intelligent inverter for stud welding in automotive rework and robot backup, and for general sheet metal fabrication applications.

The new portable inverter combines the virtues of precision and simplicity. High repeatability, accuracy and arc stability are ensured with digital signal parallel processing and Dual Loop™ fast arc regulation technology, designed for stud welding. High surge current is provided with unique Parallel Silicon™ technology for advanced high strength steel and to overcome adverse surface coating. A user-friendly interface called Stud Expert™ introduces a new programming methodology based on application conditions instead of machine settings such as time and current. Procedures can be memorized and recalled by the use of pre-sets. Quality assurance is embedded inside the welder to determine weld quality and to monitor production data.

INTRODUCTION

Stud welding to sheet metal is characterized by the use of high current and short time, which can be accomplished by a special drawn-arc stud welding process known as “short cycle”, or by capacitor discharge (CD) process.

The CD process is typically avoided in automotive and other sheet metal fabrication when quality is a must. To ensure precision control of the welding arc in weld duration as short as 5 ms, an inverter is typically used with a servo-electric gun mounted on a robot arm in automotive production.

However, virtually all automotive plants have re-work or repair stations, and a back-up system with manual stud welding when the robots are off-line. The existing automotive inverter stud welding system designed for robot is too complicated, expensive and bulky for use as backup or repair. The traditional SCR based stud welders are simple to use but have lacked the precision needed for these applications. A user-friendly, portable and intelligent stud welding system for human operator is needed for sheet metal fabrication.

INVERTER FOR MANUAL SHEET METAL STUD WELDING

High Power and Low Weight

Sheet metal stud welding is characterized by very high amperage (e.g. 1500A), very brief weld time (10-100ms) and without ferrule. As shown in Figure 1, the 77 lb inverter can output 1500 A, 100 ms at 34 studs per minute duty cycle. In order to accomplish both the low weight/size portability requirement and the high power output requirement, a combination of the latest control and power electronic technologies were implemented. Dual Loop control monitors both primary and secondary current feedback and adjusts inverter switching pulse width quickly to react to physical conditions in the arc and fluid dynamics at the stud end and base metal. Parallel Silicon provides surge power needed for sheet metal stud welding with optimum heat transfer efficiency in the switching components. Another advance is the transformer design called Turbo Planar™, with compactly stacked printed circuit boards as the main inverter transformer assembly, fine-tuned for stud welding.

Figure 1. Portable stud welding inverter shown with manual-load handgun

Programming with Stud and Weld Conditions

The requirement of interfacing with human operator is very different than with a robot. Traditionally, a stud shooter must set up the welder using current and time. These settings vary depending on stud type, size and material, weld position, and many other factors. To simplify the setup, the inverter allows operator programming based on application conditions. Large quantities of welds were performed to produce the optimum, most robust welding parameters to train a database, called Stud Expert™ to be loaded into the stud welder. The database contains welding knowledge for various alloys, polarity, stud types and diameters, welding position, and plate conditions. In most cases a stud shooter simply selects a stud from the scroll list on the inverter front panel and welds away.

Presets, Recall and Lock-out

Another important aspect for interfacing with a human stud shooter is the ease of weld program save and recall. Backlit preset buttons are provided similar to a car radio. Each preset can be associated with a particular stud in an automotive plant. A preset button can be held down until the backlight comes on to acknowledge that the settings are stored. Pressing on any preset button will recall the stored settings. Different security levels with pass code protection can be set up for production, maintenance, or programming.

Weld Quality and Production Monitor

To ensure the quality of each stud weld, the computer control is trained with a signature of good quality weld for a given stud and weld condition. A built-in weld monitor examines arc signals and compares them with the known signature of good weld. The result of the comparison is shown visually on the front panel of the welder after each weld: green plate to indicate good weld and red plate as bad weld. The front panel also displays the operating condition of the handgun, which can be a common source of problems. In addition, there is a good/bad weld counter in the welder for each pre-set, which can be used for quality assurance purposes. This information can be up-loaded to a host computer software called Nelware™, along with other production data, such as studs per day, per shift, up time etc. and trouble-shooting or service data.

Manual Stud Loading and Gun Positioning

When a hand held manual loading gun (Figure 1, right) is used, the outside diameter of the spark shield mounted on the front of the gun is usually used as the reference to locate groups of studs. Templates are commonly used with holes for the spark shield. When the spark shield is inserted into the holes in the fixture the studs will be welded at the desired locations. Alternatively, a laser marking system or a localized GPS receiver on the gun can be used to locate stud locations.

Changing the diameter of studs that are being weld with the handgun is a quick and simple operation. The chucks have a male Morse taper that is simply driven into a female Morse taper on the front of the gun. A series of chucks is available for studs in metric or imperial dimensions.

Automatic Stud Feed System

Besides manually loading studs, it is often desirable to automatically feed the stud with a feeder to boost productivity in sheet metal fabrication. The feeder and auto feed handgun shown below in Figure 2 perform the material handling aspect of the stud welding process. These components are specifically designed to work in harsh environments and reliably deliver the fasteners from the hopper in the feeder to the electrode tip of the gun in a fraction of a

second. This allows the operator to move the gun from one weld position to another quickly welding studs at rate over 20 studs/minute.

Figure 2. Stud feeder (left) and auto feed floating lift handgun (right)

SHEET METAL STUDS

Many stud configurations shown in Figure 3 can be fed with a stud feeder, which are explained in the ensuing sections. These studs are used for attaching automotive trim, fastening brackets, routing electrical harnesses and hydraulic lines, and grounding electrical circuits.

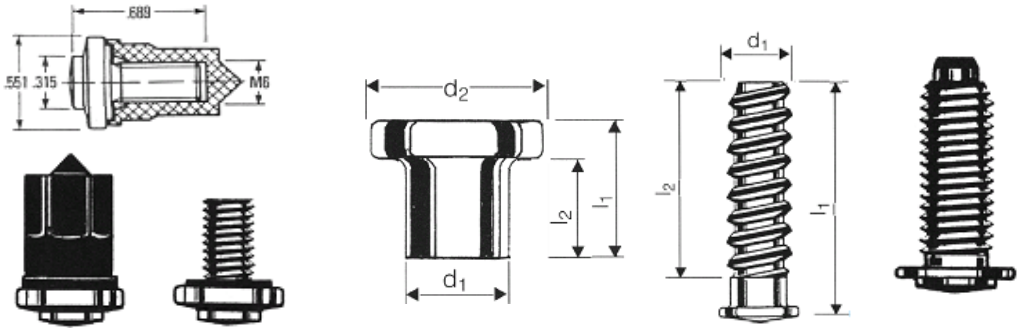

Figure 3. Electrical grounding studs (left), unthreaded trim stud (center), fir tree stud and wide top stud (right)

Flanged Stud for Sheet Metal

The strength of the fastened assembly on sheet metal is limited by the sheet metal, when the sheet metal is thinner than 1/3 of the stud diameter. The traditional fasteners for stud welding have flanges on the weld end that are normally about 1mm larger than the diameter of the stud. The flange provides a weld base with a cross sectional area that is slightly larger than the area of the stud. This extra area gives the stud the potential for the weld to always be stronger than the threaded portion of the studs. An additional benefit of flanges on these studs is for auto feed. The feeding equipment can use the flange to hold and orient

the studs. The flange assures that the right end of the stud is presented to the gun and base material for welding.

Wide Flanged Stud (W-Top)

The W-top studs have been widely adopted for use in a variety of industrial application where high strength and reliability are needed. The standard W-Top has a M6 thread and is available in different lengths. On the end that is not welded they have a dog point to facilitate the alignment and rapid installation of nuts. The W-Top studs have a weld base diameter of 9mm and an even larger collar diameter of 13mm. This collar is only 1mm thick and is located only 1mm above the weld end of the stud.

When nuts are being installed on the threaded portion of welded W-Top studs the 13 mm collars will resist the clamping force that is applied as the nut is tightened. Since the clamping force that is applied by the inclined plane of the threads is isolated against the collar the weld and the base material will not subjected a tension load. This means that dimples will not be pulled in the base material as the nut is tightened. The weld and base material only have to resist the pure rotational force as while the nut is being tightened. After the nuts have been tightened the welds and base material only have to support the weight of the part and any loads that are applied to those parts.

The 9mm diameter weld base on the M6 W-Top stud provides a large area of fusion. This weld has usually enough strength to support the strength of the M6 thread even on thin base material. The portable inverter has the amperage needed to weld the W-Top studs even at the short weld times to prevent burning through on the thin 0.7mm base material.

The typical weld settings needed to weld W-Top studs to 0.7mm steel using a hand held gun are approximately 700A at 60ms. With zinc-coated sheet metal, the use of stud positive polarity (also known as reverse polarity) often yields higher weld strength.

SHEET METAL APPLICATIONS OF THE INVERTER

Several sheet metal fastening applications using the portable inverter with auto feed are shown as follows.

Flanged Stud on Air Bag Inflator

Figure 4 illustrates a 6 mm small-flanged stud welded to an air bag inflation canister, using short cycle gas arc process. The studs are welded to the canister to provide a means to mount the air bag inflators in an automobile. The welds are made at 400 A and 80 ms, with an ultimate tensile of 9,520 N. The weld must be strong but cannot cause any backside distortion, which would interfere with the contents of the canister.

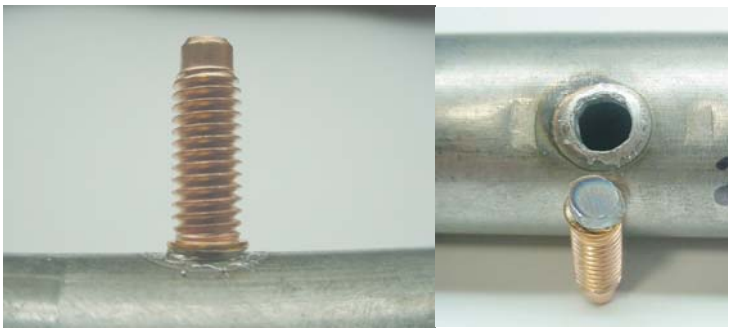

Figure 4. Small-flanged stud welded to an air bag inflator

Examples of W-Top and Fir Tree

Another application requires an 8mm stud to be welded to a 44mm diameter steel tube of 3mm wall thickness. A wide top stud (W-top) is short cycle welded with 1100A and 70 ms with gas shielding. The stud provides a mounting base for other components (Figure 5 left). A 5mm fir tree stud is welded to a mild steel sheet metal (Figure 5 right) to hold press on clips at 600A, 30ms.

Figure 5. W-top to a 44mm tube (left) and fir-tree to hold press on clips (right)

W-Top on "Quiet" Steel

Short cycle is used by the inverter to weld a W-top stud to laminated steel dash panel (Figure 6, right). The laminated steel is used to reduce noise from the engine compartment. The sheet is comprised of two sheets zinc plated steel that are less than 0.5mm thick with a thin sheet of polymer between the two sheets of steel. The total thickness of the laminated sheet is only 1mm. To get good welds on this material very short time and very high amperage were needed to prevent burning through the material. The weld settings are 1200 amps at 10ms.

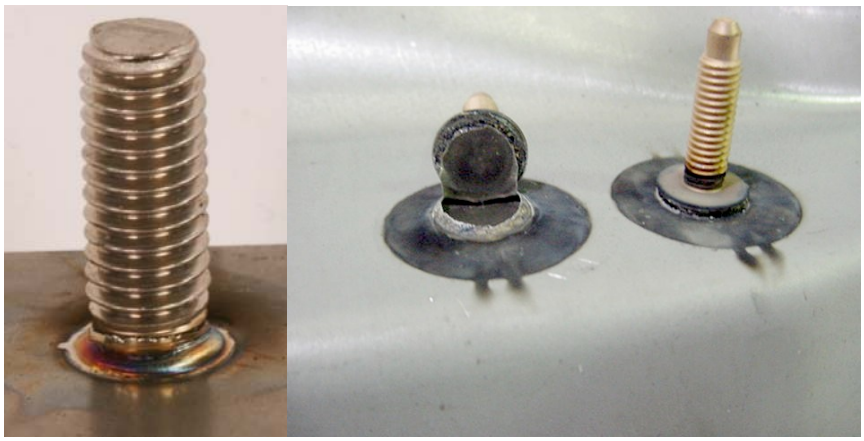

Figure 6. 9.5mm diameter stainless stud short cycle welded without ferrule (left) and W-top welded to laminated steel (right)

Stainless Stud Welding without Ferrule

Short cycle with gas shielding arc is successfully implemented by the inverter to replace drawn-arc with ferrule. Figure 6 illustrates a 9.5mm small flange, stainless steel stud welded at 900A, 75ms with argon shielding and automatic feeding.

STUD WELDING VS. RESISTANCE WELDING

Spot welding and projection welding are commonly employed to weld sheet metal. One of the significant advantages of the stud welding process is single-side access. Another advantage is low pressure applied to the surface of the sheet metal, in contrast with the large clamping force needed for resistance welding.

The added benefit of portability of the stud welding inverter and handgun system makes it a more versatile tool than resistance welding in certain automotive applications.

CONCLUSION

A portable and intelligent inverter is introduced to weld studs in demanding sheet metal short cycle stud welding applications. It provides a cost-effective solution for use in both automotive rework stations and manual production, and in general sheet metal fabrication such as electrical enclosure, switchgear, HVAC and transformer manufacturing. The portable inverter can be used either with manual stud feed or auto-feed, and either with or without gas shielding. W-top, threaded stud, fir tree and T-studs can be welded, with material including steel, stainless steel, laminated steel, and other material such as aluminum, advanced high strength steel and Inconel.