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- Method for defect-free hybrid laser-arc welding of closed circumferential welds

New perspectives in stud welding quality management

Ever since the stud welding process came to Europe from the USA during the 1950s, it has been used to perform numerous mounting tasks faster and more safely. Wherever a "small" fastening device needs to be attached to a "large" component, stud welding plays an important part. For hundreds of threaded studs on a car chassis, thousands of anchoring bolts in furnace and boiler construction, or ten thousands of shear connectors in composite bridge construction, economical and simultaneously safe manufacturing would be unthinkable without the various types of stud welding processes, such as arc welding with ceramic ferrule or shielding gas, or short-cycle stud welding.

Welding connections – how reliably can they be checked?

Anyone dealing with welding technology, however, knows that the possibilities for a 100% check of welding connections are very limited. After all, we cannot see into the inside of the welding zone. Destructive tests can only be carried out on a few random samples; non-destructive tests are generally costly, and therefore in many cases not an option for a complete check of all welds.

Moreover, as quality cannot be examined inside the connection, it must be ensured beforehand.

This is why demonstrably safe execution of the welding process is of vital importance.

There are many technical standards dealing with quality management in welding technology. Prior to every welding operation within the regulated areas, which also include the building industry, a welding procedure specification (WPS) must be prepared and verified. Welders, in the case of stud welding, operators, require an examination certificate. Where high quality standards are necessary, the welding equipment must be calibrated as well.

The rules laid down also include a specification of what must be observed during welding to make sure that the expected result is actually achieved. This, at least, is the theory.

But what happens in practice? Are welding procedure specifications always complied with? Is the welding equipment invariably in good order and condition? Has the operator understood what a safe welding process requires? Can the welding supervisor be sure that all requirements have been met? Can we always rely on the human factor?

Special characteristics of stud welding

Stud welding is an "automatic welding process", therefore it could be assumed that nothing can go wrong here. But since this is not the case, some requirements to be met by welding staff have been included in the EN ISO 14555 standard, chapter 6, according to which:

"Stud-welding operators shall have appropriate knowledge to operate the equipment, to adjust it properly, to carry out the welding correctly and, while doing so, to pay attention to good contact and suitable connection between the work piece cables and uniform distribution of ferromagnetic materials (see Table A.8). The welding personnel shall be qualified in accordance with ISO 14732. [...] Welding coordination personnel for stud welding shall have knowledge of and experience in the relevant stud-welding process, and shall be able to select and set the correct parameters, e.g. lift, protrusion (plunge), current intensity, and welding time."

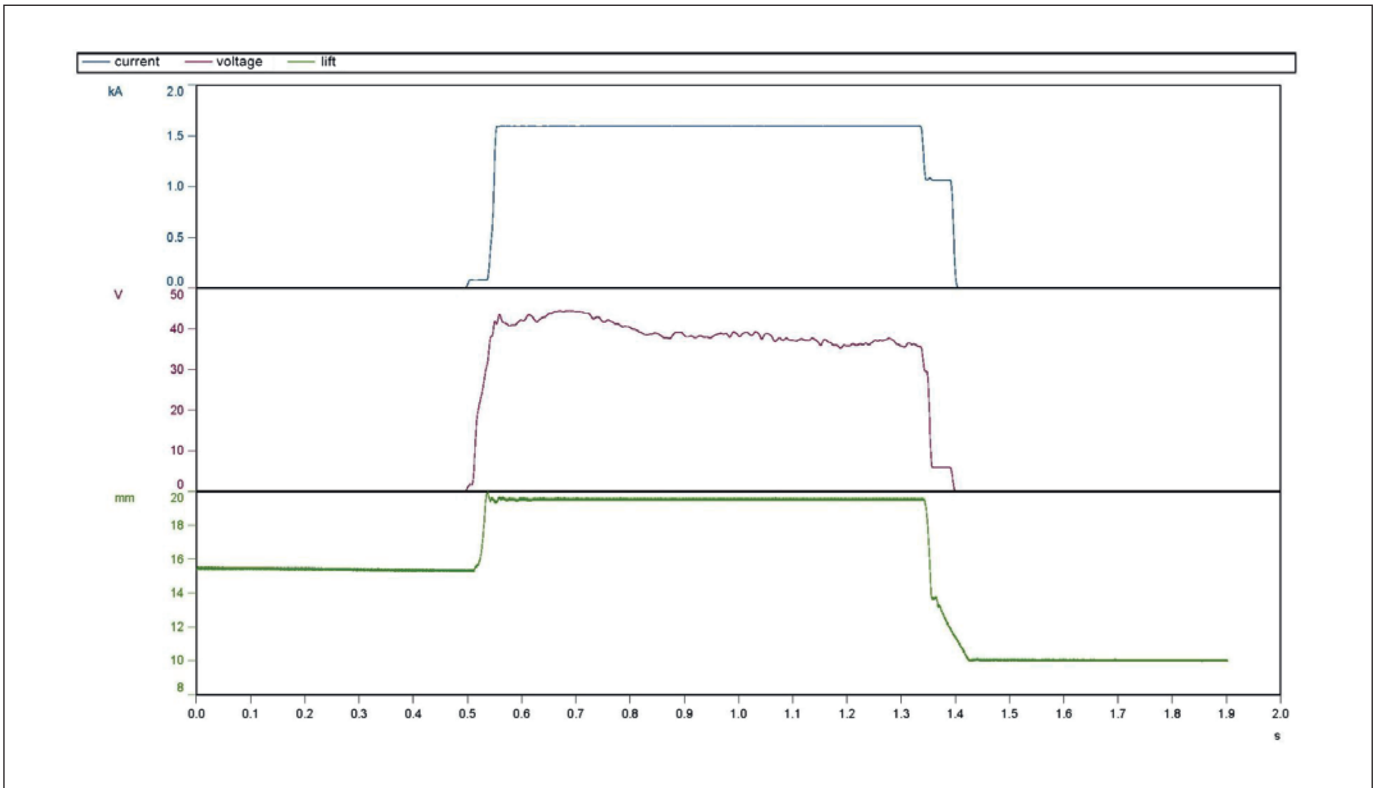

Fig. 1 • Process of a drawn-arc stud weld compliant with the rules. (Pictures: DVS (8), Bolte)

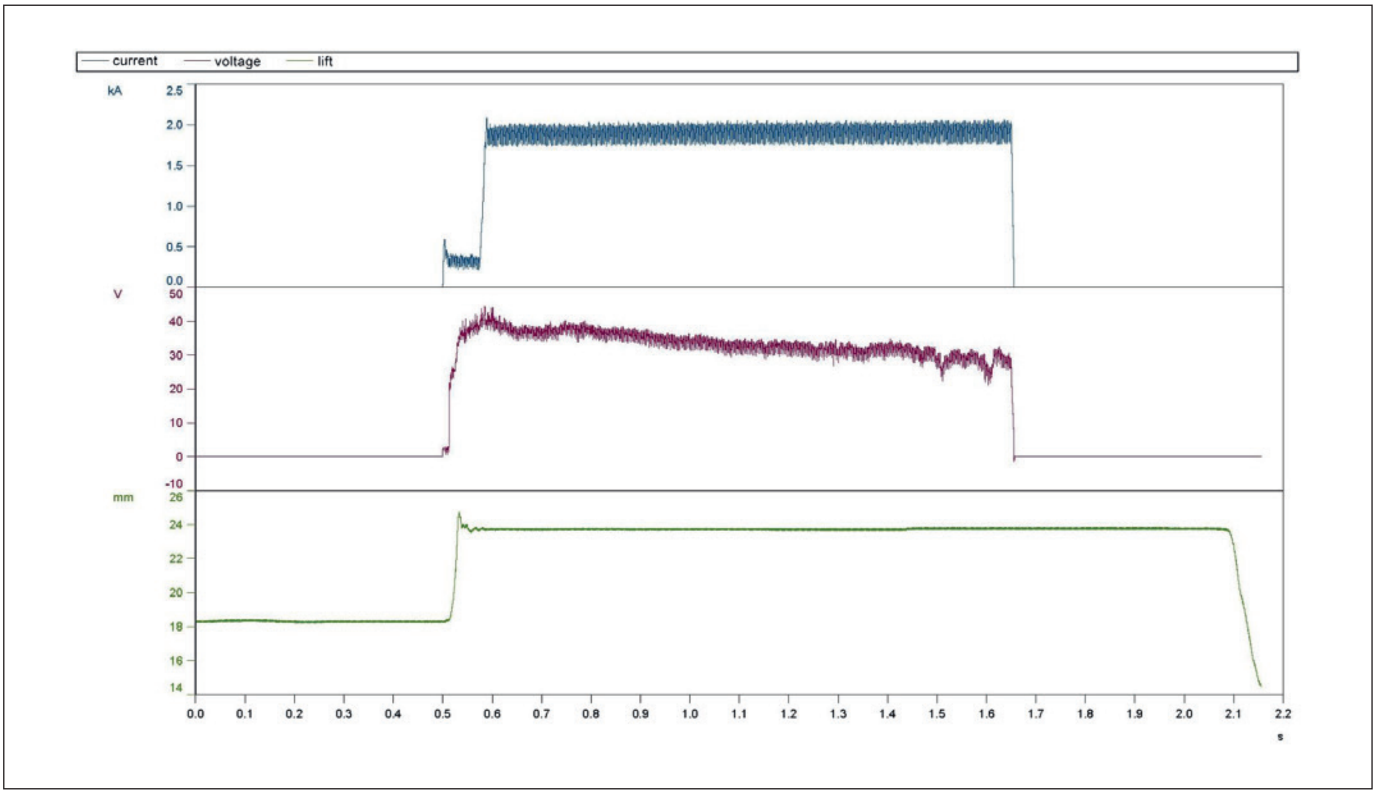

Fig. 2 • Process of a stud weld with cold-plunged stud.

Let us assume that both operators and supervisors have complied with all of these requirements and that a perfect stud weld has been produced. However, how can it be confirmed that in all welds carried out, even in the ten thousands, all requirements have been fulfilled? The frequently applied bend test cannot be the solution, since it is more or less destructive.

Non-compliant shear connector welds carried out in North Rhine-Westphalia, Germany steel components for a major steel construction project in 2019 have proved that this is more than just an academic question. Here, unsuitable welding equipment caused massive faults in the weld zone, which could not be detected by visual examination, but came to light only by random bend tests. The causes were revealed by subsequent further tests carried out with process control equipment.

Fig. 3 • Small lack of fusion area at the edge due to a cold plunge, the stud does not reach the required 60° bending angle.

The goal is clear

Modern stud welding appliances provide the answer in the form of comprehensive process monitoring. The settings of welding current, welding time, lift (length of the arc) and protrusion (plunge) must be proved to lie within certain limit values, only then can an additional visual examination of the welded stud provide security.

Electronic recording and analysis of the welding current and welding time has already been common practice for several decades. A more complex task, however, is monitoring of the stud movement, a decisive factor in welding. If this movement is not coordinated precisely with the “current programme”, a so-called “cold plunge” may occur. If the stud is not fused with the workpiece during the arc phase, but only afterwards, even a delay of a few milliseconds will immediately cause an oxide layer to form on the melt while it is no longer protected by the pressure of the arc. This leads to a more or less extensive lack of fusion, which can hardly be detected by visual examination!

Fig. 4 • Undercutting caused by a plunge impediment.

Fig. 5 • Massive lack of fusion at the edge due to a cold plunge, the weld zone breaks under low load.

Fig. 6 • Inverter power sources from the "Pro-I" series.


Fig. 7 • Stud welding gun models "GD 12sc", "GD 12", "GD 16" and "GD 22" with travel measuring system.

Fig. 1 shows an example of a faultless welding process. The downward movement of the stud during the drawn arc phase is clearly recognisable. As soon as both welding pools are united, the voltage drops considerably before the welding current is switched off.

But if the welding current is switched off before the lifting coil of the welding gun (**Fig. 2**), this causes a more or less extensive lack of fusion (**Figs. 3, 4, 5**).

As already mentioned, stud welding is an automatic welding process characterised by the operator being unable to intervene during the process and certainly not in a position to correct any irregularities. Deviations from the set values can therefore only be rectified via metrological control.

The solution

Stud welding appliances such as those of the "Pro" series from Bolte GmbH, combined with GD welding guns equipped with travel measuring system, enable recording of the electrical values (current and time) as well as those relating to the stud (lift, protrusion and plunge). The "Pro-I" and "Pro-S" models use modern inverter technology to ensure not only a smooth welding current, but also economical consumption of electrical energy. What is more, the appliances' wide-range power supply unit enables operation with voltages ranging from 320 to 495 V, which makes the equipment function trouble-free even with generators on building sites (**Figs. 6 and 7**). The "Pro-D" appliances still rely on the traditional thyristor rectifier.

To some, the meaning of the terms protrusion and plunge is not clear. Protrusion is a parameter which needs to be set beforehand. Plunge designates the amount of downward movement made by the stud until it comes to a stop.

It is influenced by protrusion, spring tension, gravity, damping, etc. and can reach a maximum value which equals the sum of lift plus protrusion. Where a flat collar is desired, a shorter protrusion is set, which reduces the plunge accordingly – and vice versa. The diagram (**Fig. 8**) illustrates the movement process.

On Bolte "Pro" appliances, the operator can now set not only the current and time, but also lift and protrusion prior to welding and read the values on the display of the power source without carrying out an actual weld **(Figs. 9 and 10)**. For this purpose, the gun is placed on the workpiece and an operating cycle is simulated. It is subject to exactly the same conditions as would prevail in a real welding process. In contrast to some other stud welding systems, the parameter settings are not only adjusted here, but also measured by a precise sensor and thus verified.

The lift is altered by adjusting the stop screw on the gun, the protrusion by shifting the legs. After all values have been properly set, a test weld is carried out on a few studs and analysed. The stud welding appliances from the "Pro" series save 10 welds as standard, including the values for current Is, time ts, voltage U, lift L, protrusion P, the plunge MD and the plunge speed vp.

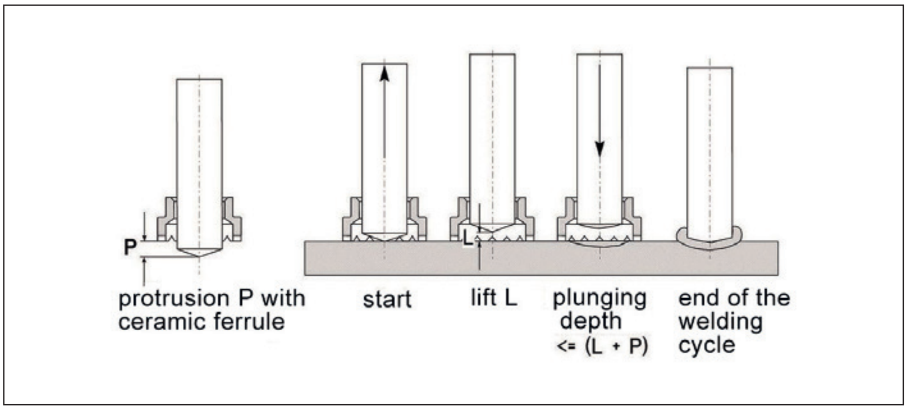

Fig. 8 • Schematic diagram of the drawn arc stud welding process (according to DVS-M 0902).

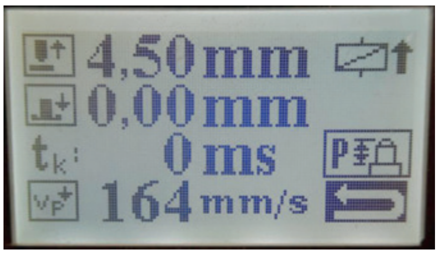

Fig. 9 • Measurement values following a cycle simulation: lift, plunge, short circuit time, plunge speed.

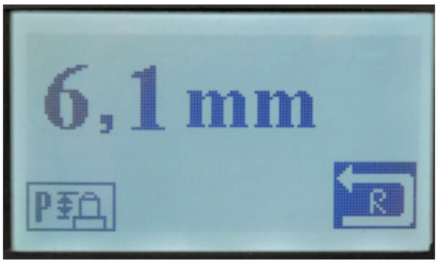

Fig. 10 • Display of protrusion after a cycle simulation.

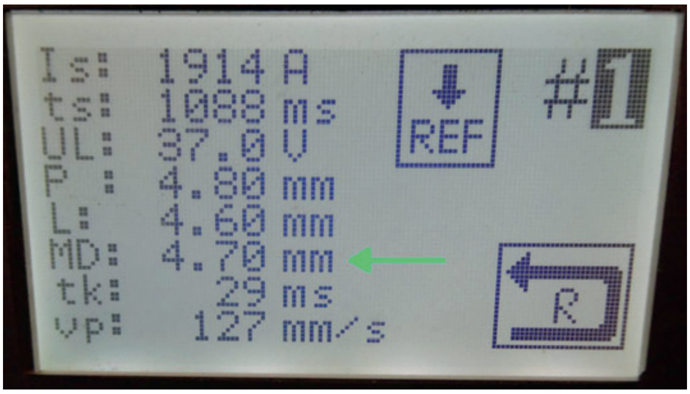

Fig. 11 • Measurement values after a weld with display of the desired plunge (green arrow).

The appliance also recognises whether the welding pools have been united "hot", i.e. under the burning arc, and shows the short circuit time tk. If this value is greater than zero, it is proof of a "hot plunge". If the welding supervisor is satisfied with the result of the visual examination, the weld will be saved for reference. Then an upper and lower tolerance margin can be fixed, and if this margin is exceeded, an alarm will be triggered. In this way, faulty welding results will be noticed immediately, which enables the welding supervisor or the operator to intervene.

Fig. 11 shows the display of a perfect weld and **Fig. 12** shows the welded stud, the relevant curves are shown in **Fig. 13**. The short circuit time, which is particularly important here because a "cold plunge" in production can only be detected by precise measuring, was measured at 30 ms by an external measuring device (the time shown between the two vertical lines), a perfect match with the value shown on the display of the power source.

The same applies to all other quality-determining parameters.

If, for example, the arc is deflected through welding at the edge in spite of all parameters being set correctly, the stud is only melted on one side and therefore falls short of the normal plunge. Here the great advantage of power sources from the "Pro" series and "GD" guns with travel measuring system becomes obvious. **Fig. 14** shows the display, where the extraordinarily short plunge (1.6 mm instead of 4.7 mm in a good weld) can be recognised immediately. **Fig. 15** illustrates the relevant welding results.

If desired, up to 25,400 welds can be saved on a PC by means of an optional extension for further statistical evaluation.

The most recent General Circular for Composite Bridge Construction (GC No. 18/2019) has raised the required standards for shear connector welding in composite bridge construction considerably. It is no longer permitted to repair non-compliant welds by manual re-welding. Where Bolte "Pro" appliances are used, the appliance can immediately register every deviation from the permissible ideal values and so the welding supervisor or the operator can

Fig. 12 • Weld with the measurement values shown in Fig. 11.

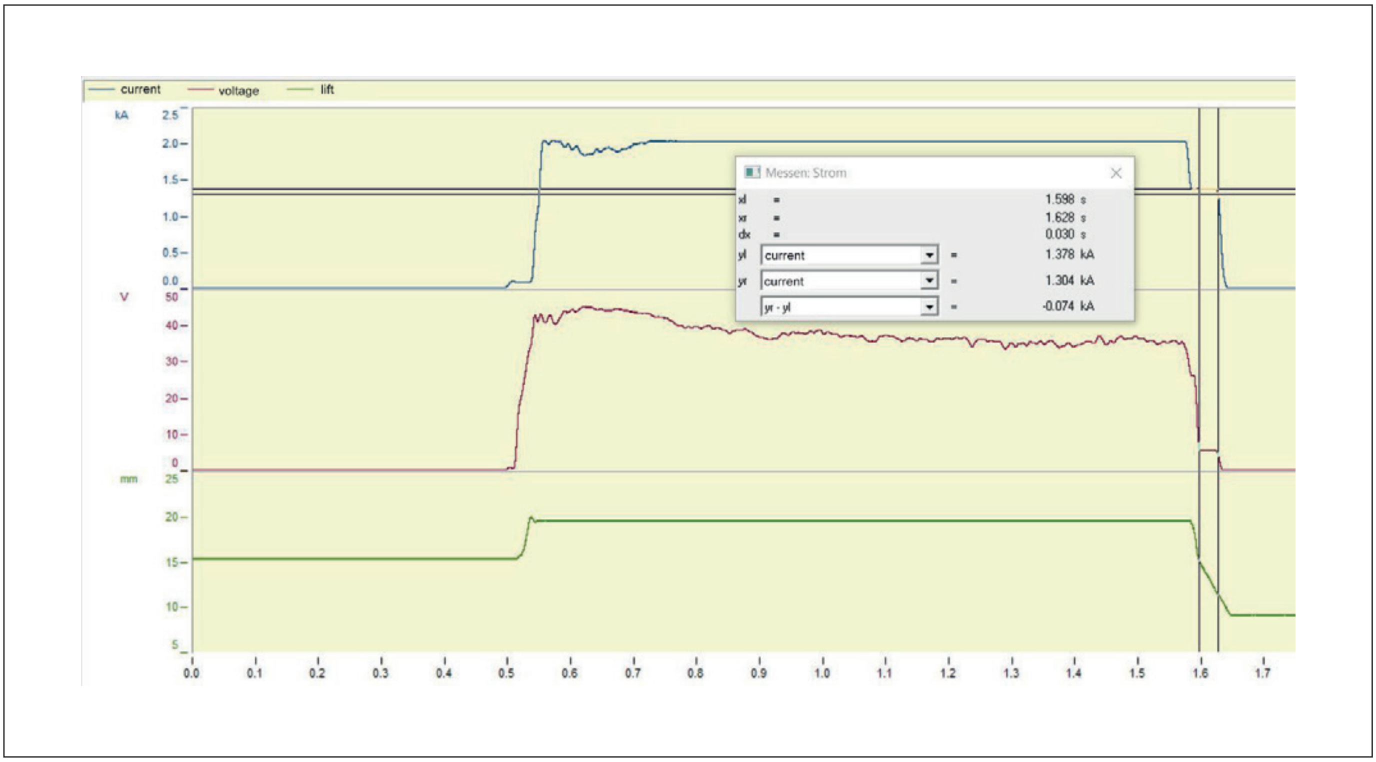

Fig. 13 • Correct stud welding process with hot plunge, short circuit time 30 ms.

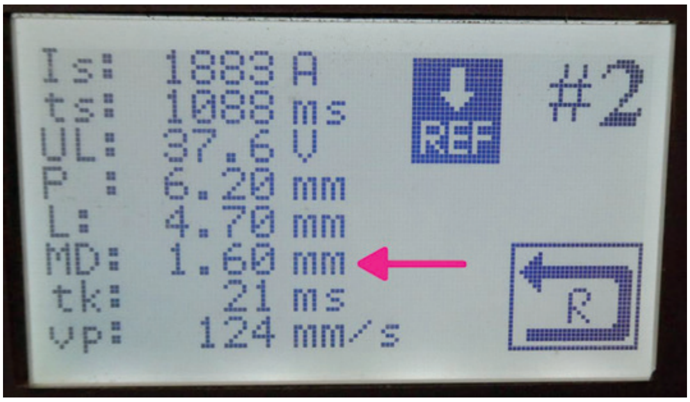

Fig. 14 • Measurement values from a weld with melting of the stud on one side, and too short plunge (red arrow).

Fig. 15 • Welding results with the values shown in Fig. 14.

detect any welding faults in time, such as insufficient compensation of the blowing effect, tilting of the gun, among others. As a result, production monitoring can be restricted to having all welds monitored and recorded by the power source and subsequently checked by visual examination.

Verifiable safety

Stud welding is a program-controlled automatic welding process, for which welding supervisors and operators must set up the necessary conditions for faultless results prior to starting the weld.

Bolte stud welding appliances from the “Pro” series offer not only excellent welding attributes, but are also able to monitor every important parameter and to save and analyse the actual values. Together with visual examination, the system thus ensures proven safety and is setting new benchmarks for requirements to be met by high-quality stud welds.

Rainer Trillmich,
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