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SPECIAL EDITION

SRM stud welding – a new arc stud welding variant

In SRM stud welding (welding in a radial-symmetric magnetic field), a radial-symmetric magnetic field in combination with a shielding gas atmosphere protects the arc from external influence. This results in higher efficiency due to repeatable, high welding quality without arc blow problems. In practice, this means very even and defined partial melting of stud and sheet with considerably reduced energy input into the welded connection, reduced spatter formation and a small bead.

The arc is protected in the area of the welding point. Without this additional protection, there are often blow effects on the arc considerably disturbing the application of the drawn arc stud welding procedures resulting in incomplete bead formation and/or undercutting. So the user has to deal with additional expenses in the ongoing production monitoring, however also in regularly required work tests and/or procedure qualifications according to DIN EN ISO 14555.

The new stud welding in the radial-symmetric magnetic field can make an important contribution to the improvement of the arc stud welding efficiency by repeatable, good welding quality, basically without blow effect problems. A characteristic feature of SRM stud welding is an extremely even and defined partial melting of stud and sheet with a considerably reduced energy input into the welded connection, reduced spatter formation and a small bead.

Transferring the advantages to larger stud diameters

Arc welding using the SRM technology results from first experience in 2005 [1] for studs up to a diameter of 10 mm at alloyed steel. In 2009, Heinz Soyer Bolzenschweißtechnik GmbH, Wörthsee/Germany, presented this technology to an international audience on the occasion of the "Schweissen & Schneiden" Fair in Essen. The reaction to the welding results of the SRM technology with simultaneous use of a patented special welding stud of type "HZ1" by Soyer was already very positive. For studs with a diameter of more than 10 mm, however, no empirical values were available then. In the industry, there were requests regarding the applicability, especially with larger stud diameters, and for out-of-position welding to both the Welding Training and Research Institute SLV Munich and the machine manufacturer.

In the further development of the SRM technology, it has in the meantime been possible to transfer its advantages regarding the use of the comparatively little energy input and the small, however very even weld penetration geometry to studs of sizes M12 and M16. At these diameters, as well, optically appealing welded connections could be produced, hardly causing any rework due to disturbing bead accumulation and spatters. The determination of relevant characteristics and the optimisation of the welding and boundary conditions were completed within the scope of a research project of Bayerische Forschungsstiftung (Bavarian Research Foundation), Munich.

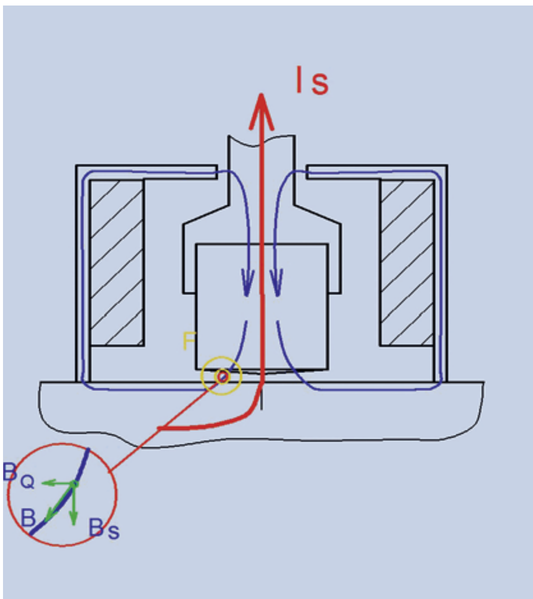

Fig. 1 • Sleeve or nut welding with the support of a magnetic field for the even movement of the arc at the ring-shaped hollow section: welded sleeve connection at alloyed steel with good bead appearance (top), a magnetic field surrounds the welding point and together with the shielding gas, results in the arc movement (bottom).

The benefit of the SRM technology was discovered in 2005 rather accidentally. Before, magnetic fields were used in stud welding primarily for the even movement of the arc at a hollow section, similar to MBP welding (pressure welding with magnetically moved arc) (Fig. 1). This technology developed as sleeve or nut welding [2, 3] has been used with an additional fixture for the creation of the magnetic field and the shielding gas cover in the market for years. The shielding of the welding point by a magnetic field in order to reduce unintended arc deflection has also been known for years; it has, however, only established itself in individual cases, for example with alloyed materials.

The SRM technology is an extension of drawn arc stud welding for common, unalloyed and alloyed steel materials that are suitable for stud welding. The weld pool protection is implemented by means of commercially available shielding gases (argon or mixed gases with CO_2) in combination with magnetic arc influencing. A ceramic ring is not necessary. The SRM technology distinguishes itself by the following features:

- high welding quality with smooth bead surface, little weld penetration depth and high carrying capacity,
- welding process with little blow effect,
- good repeatability,
- little welding energy and thus only minimum distortion of the component,
- all welding positions possible (downhand position, vertical wall, overhead).

For studs of sizes M12 and M16, welding conditions for the creation of highly loadable stud welds were determined after development of the suitable shielding gas magnetic field additional device; these conditions comply with the current requirements of DIN EN ISO 14555 with regard to bending and tensile load as well as weld penetration shape.

Very simple device extension

Fig. 2 shows the course of the SRM welding procedure as variant of drawn arc stud

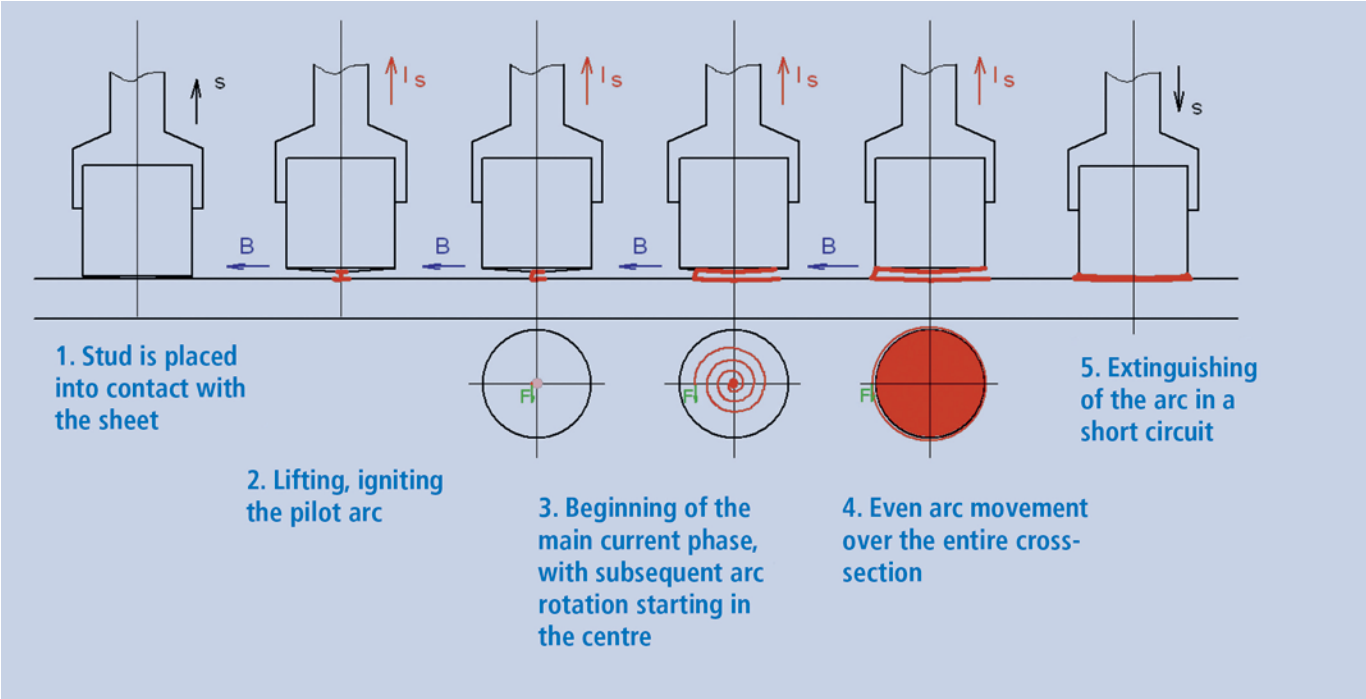

Fig. 2 • Procedural process in SRM welding as variant of drawn arc stud welding: The magnetic influence on the arc leads to the even partial melting of the entire front face even with full cross-sections with identifiable rotation effects during the main current phase.

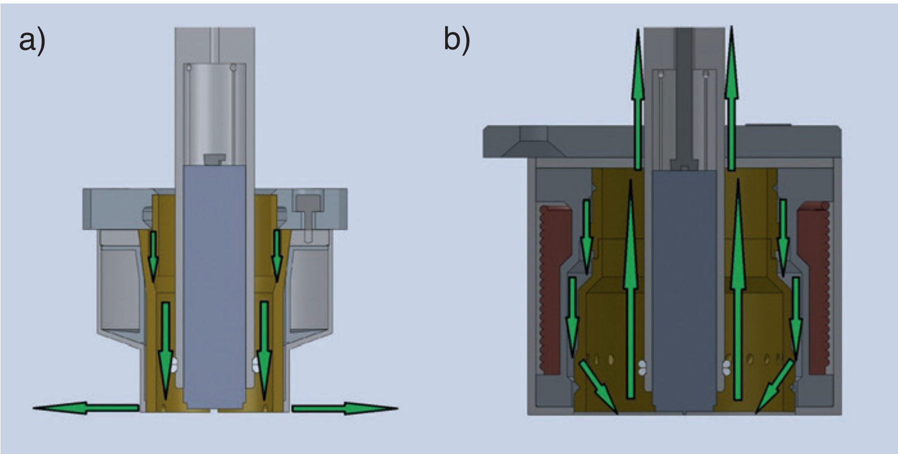

Fig. 3 • Additional fixture with different degassing concepts to create magnetic field and shielding gas cover: a) small size up to M12, b) larger fixture for M16 with changed gas flow direction.

Fig. 4 • SRM welding gun for M16 studs – the connection of the magnetic field shielding gas fixture to the support feet of welding guns and welding heads is also easily possible with stationary handling.

welding. Except for the actuation of the radial-symmetric magnetic field, the welding process exactly corresponds to drawn arc shielding gas stud welding. Before the beginning of the main current phase, the additional magnetic field is activated which subsequently influences the arc with regard to its movability of the arc starting points at stud and sheet even with complete cross-section. The entire front face of the stud is evenly partially melted within a shorter period than in the drawn arc procedures known until now. In this phase, partial rotations of the arc around the stud axis with increasing rotation radius are identified.

The device extension for the SRM stud welding is very simple. Depending on the diameter, you use the commercially available "PH-3N" welding gun for M12 or "PH-4L" for M16, which are in each case equipped with an optimised SRM shielding gas magnetic field fixture according to Fig. 3. For the M12 studs, there is a small, compact fixture (Fig. 3a) that is hardly larger than a common shielding gas fixture. For M16 studs, the fixture according to Fig. 3b was enlarged accordingly, whereas the gas flow direction and the degassing concept have been changed. With the "BMK-16i" (up to M12) and "BMK-30i" (currently up to M16) inverter power sources by Heinz Soyer Bolzenschweißtechnik, the magnetic field is activated by an SRM module which can be retrofitted. These inverter power sources are especially suitable for stud welding using the SRM technology.

SRM welding does not require special training of the users. The stud welding parameters are basically set at the welding guns, welding heads and at the power source, as usual. In addition, you only need to set the current intensity for the SRM magnetic field to up to 1.5 A depending on the magnetic coil.

Fig. 4 shows the adapted magnetic field shielding gas fixture at the support feet of the "PH-4L" welding gun with additional electrical connection to supply the magnetic coil. This is basically also possible when using welding heads with stationary operation. As shielding gases, you can – in addition to pure argon – particularly use mixed gases with 2.5, 10 or 18% CO_2 share. The mixed gas Ar + 10% CO_2 has proven of value in case of high requirements regarding bead appearance and carrying capacity of the SRM welded connections.

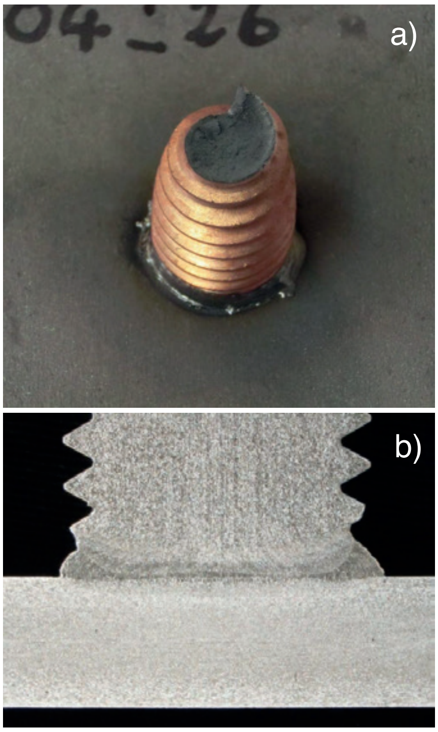

Fig. 5 • View and weld penetration shape of a SRM welding connection with M12 stud made of S235 material (stability class 5.8); the tensile test resulted in a fracture position in the stud after contraction in the thread – a) complete bead formation, fracture position in the stud, breaking force 50.5 kN, b) even, thin melting zone, little weld penetration depth in the sheet, no weld defects visible.

Similar welding result for M12 and M16 studs

Results for M12 studs

The effect of the influenced arc in SRM stud welding becomes particularly clear in the weld penetration geometry. The very even partial melting is similar to that in the capacitor discharge stud welding procedure in which the sheet only shows little weld penetration depth. The carrying behaviour of stud welding connections is proven using a simple bending test (site test) or a static tensile test according to DIN EN ISO 14555.

Fig. 5 shows the view and weld penetration shape of an SRM welding connection with M12 studs made of S235 material which has a tensile strength of about 560 MPa in stability class 5.8. Fig. 5a documents the fracture position of studs in tensile tests required according to DIN EN ISO 14555. In this example, the stud breaks at a load of 50.5 kN after contraction in the thread. In the section (Fig. 5b), you can clearly see the typical, even, thin melting zone as faultless link between stud and sheet. The weld penetration depth in the sheet is about 0.5 mm. In the area of the bead, the weld pool depth slightly increases. This weld penetration geometry is hardly susceptible to pore and crack formation if unalloyed steels suitable for stud welding are used. When dipping the stud into the weld pool, only a small amount of melt is displaced whereas a smooth bead surface with almost fillet weld shaped bead geometry results.

Fig. 6 contains statistic data for the comparison of the results of tensile tests at M12 welds for the SRM, ceramic ring and shielding gas stud welding variants when using materials from the same production batch. Every variant is based on 20 tests at studs made of the stud material S235 (stability class 5.8), welded at 10 mm thick sheets made of S355. In all welded connections, the fracture position was within the stud. Using the diagram, you can thus only evaluate the distribution of the stud material used in an overall distribution range between 49 and 52 kN. As mean values, the medians in the selected box/plot presentation are at the same level between 50.3 and 50.6 kN.

Fig. 7 contains the welding dates used regarding the individual welding variants. It shows views and weld penetration shapes of M12 studs that were welded using different drawn arc variants from Fig. 6. For this comparison, the ceramic ring stud welding was performed with a welding energy of about 6 kJ, the shielding gas stud welding with about 5 kJ and the SRM stud welding with about 4 kJ. In contrast to the SRM welds, stud welds with the ceramic ring and shielding gas variants frequently fail in the welding zone if the low welding energy of 4 kJ is used. This "low-energy concept" of SRM stud welding particularly distinguishes itself by the small bead and the little weld pool thickness. It can be determined as result of this examination without doubt that with regard to the carrying behaviour with static bending and tensile loads and with regard to the repeatability, SRM stud welding can be used as innovative

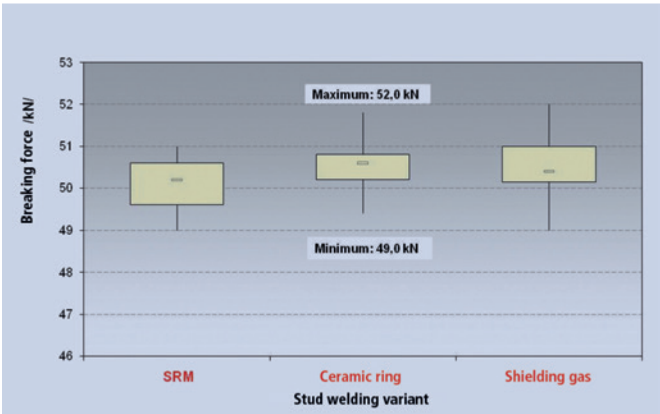

Fig. 6 • Statistics of comparative tensile tests at M12 stud welding connections – 20 tests per variant, fracture position in the stud in all welded connections, stud material S235 (stability class 5.8) from the same batch; welding data see Fig. 7; repeatability and process reliability of SRM stud welding is equal to the conventional stud welding procedures.

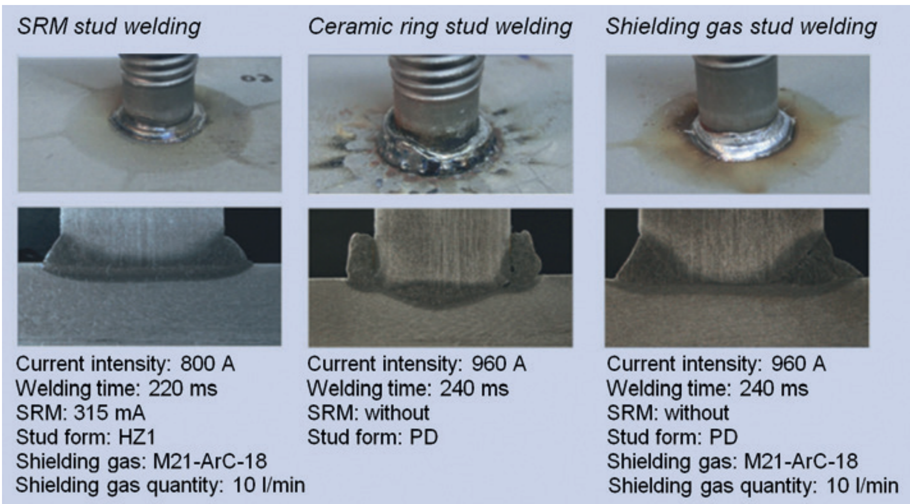

Fig. 7 • Comparison of different drawn arc variants with M12 studs made of material S235 (stability class 5.8); all studs were made of the same batch; sheet material S355, 10 mm thick. In another test series, the basic sheet material broke due to bad Z quality. The procedure requires good surface preparation and good adjustment of shielding gas and welding parameters. If this is not done carefully, failure of SRM stud welds in the welded connection cannot be excluded.

alternative to the conventional stud welding procedures (ceramic ring or shielding gas).

Results for M16 studs

In the examined SRM welds with M16 studs, the bending tests were passed without problems if suitable welding and boundary conditions were used. Fig. 8 shows view and section of an SRM stud weld at M16 studs made of material S235 with a welding energy of 6.0 kJ. With regard to appearance and weld penetration shape, the welding result resembles the previous experience with M12 studs. The welding times don‘t have to be extended as compared to smaller diameters. To ensure sufficient partial melting, only the current intensity is slightly increased from about 900 A to 1,200 A and the coil current of the larger SRM fixture according to Fig. 3b is increased to 1.1 A. In a ceramic ring stud weld with comparable design, a welding energy of about 18 kJ is used with this diameter.

The reduced and even weld penetration results in considerably reduced distortion of the component. With regard to the blow effect, the even weld penetration can e.g. also be achieved with unilateral ground connection. In static tensile tests, M16 stud welds under the shielding gases argon and Ar + 18% CO_2 break in the basic stud material at

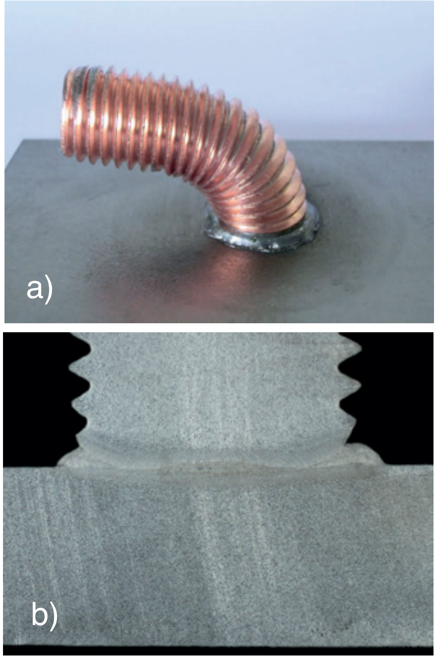

Fig. 8 • View and weld penetration shape of an SRM welding connection with a stud M16 x 60 at a sheet made of S355; a) condition bending angle of more than 60° satisfied, b) thin melting zone, slightly increased partial melting in the centre due to the influence of the shielding gas; welding conditions: current intensity: 1,170 A, welding time: 220 ms, lift: 2.8 mm, penetration depth: 0.6 mm, SRM field: 1100 mA, welding energy: 6.0 kJ, shielding gas: M21 – ArC – 18

breaking tensions of about 560 N/mm² of the stud batch used. It can be determined based on the results for M16 studs that SRM stud welding also offers potential for the economic use with larger diameters than 12 mm.

High process reliability also in out-of-position welding

One special advantage of the SRM technology becomes apparent in out-of-position stud welding, particularly at a vertical wall (PC position). Fig. 9 shows an SRM stud welding connection of an M12 stud out-of-position (PC) under shielding gas M21 – ArC – 18 with magnetic field additional fixture, carried out in the same form at unalloyed sheet steel. If you compare upper side and lower side of the weld in Fig. 9, you can see a similar and complete bead formation. From the section, you can hardly see any influence of the PC welding position as compared to PA (downhand position = sheet horizontal).

Fig. 10 shows SRM stud welding connections with M16 studs that have been welded out-of-position (PC) (at vertical wall) under shielding gas M21 – ArC – 18. In the welding connection in Fig. 10a, SRM results in a complete bead formation at the upper side of the welding. The bending test is passed. The welding connection in Fig. 10b, however,

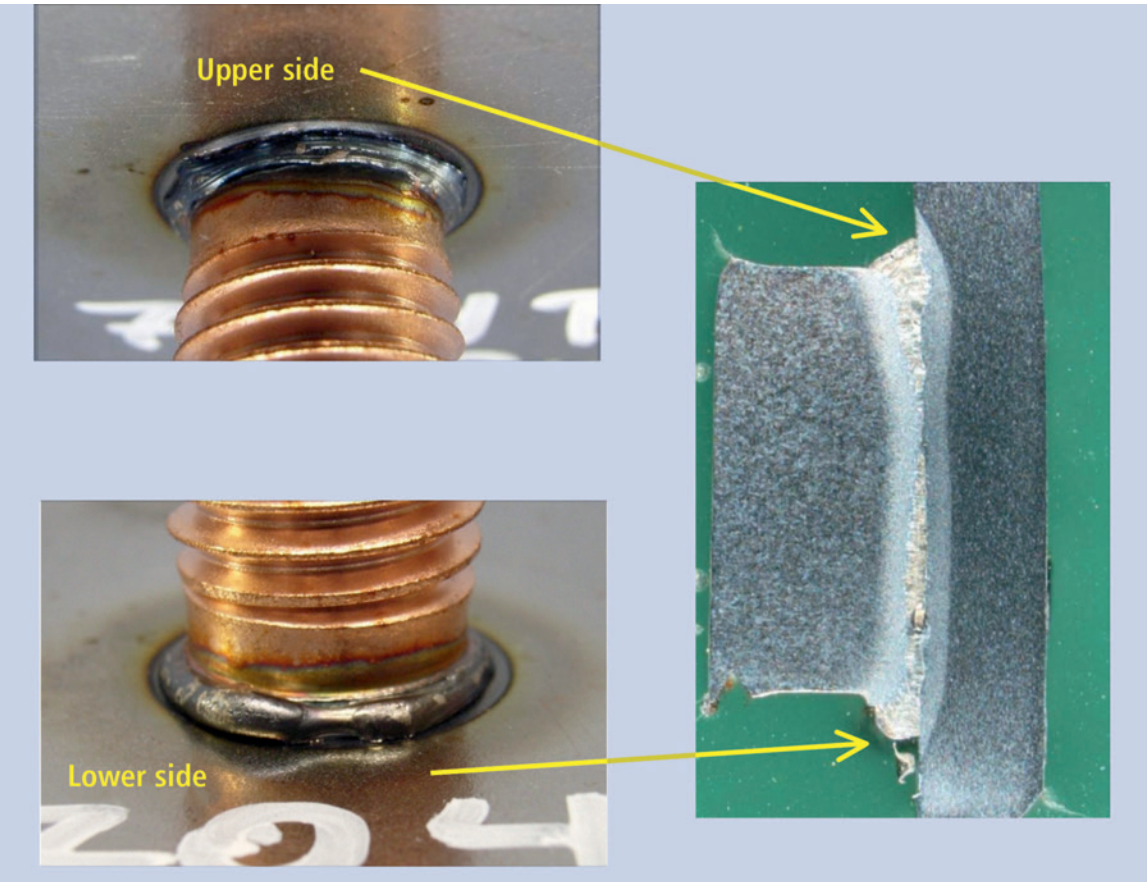

Fig. 9 • SRM stud welding out-of-position, PC (at vertical wall), under shielding gas M21 – ArC – 18 with magnetic field additional fixture, stud: M12, S235, sheet: S355, welding conditions: current intensity: 900 A, welding time: 170 ms, lift 2.0 mm, immersion depth: 0.5 mm, shielding gas: M21 – ArC – 18

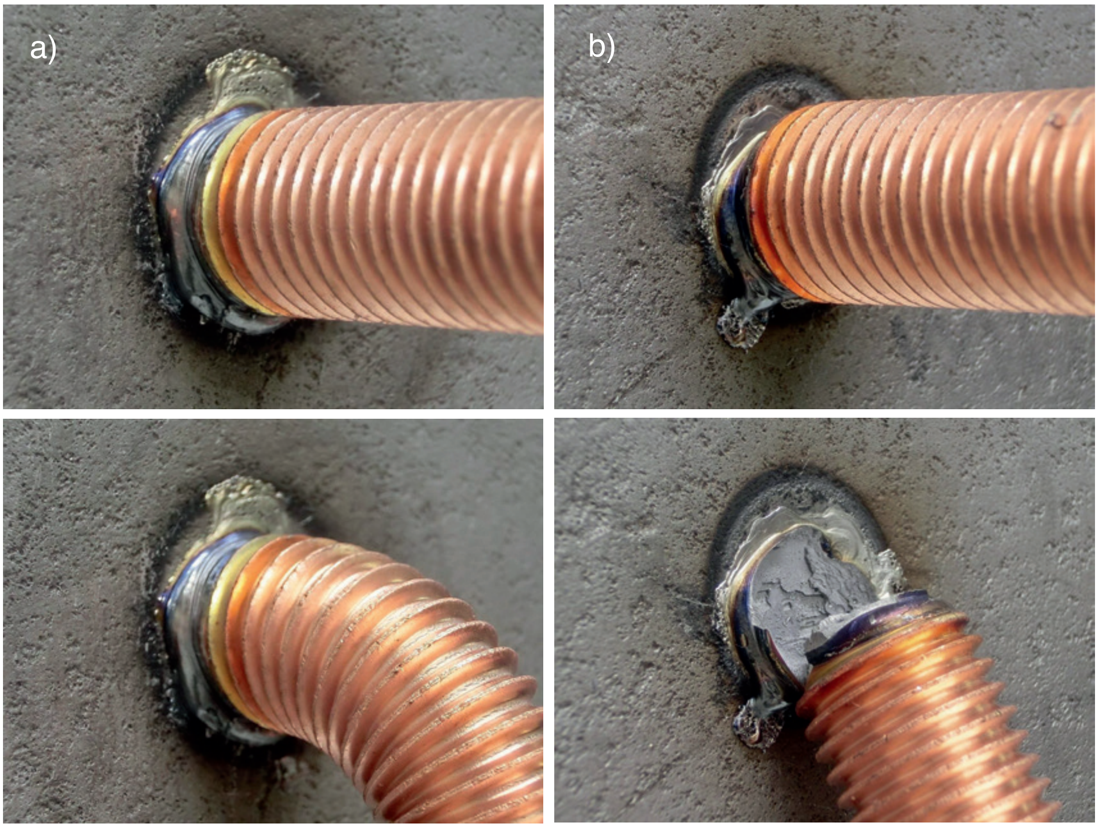

Fig. 10 • Views of SRM stud welding connections with M16 studs made of S235 at a sheet made of S355 out-of-position, PC (at vertical wall), under shielding gas M21 – ArC – 18 before and after the bending test; a) with SRM technology: even bead formation at upper and lower side of the stud, bending test with bending angle of more than 60° passed; b) without SRM technology: bead formation at upper side incomplete, fracture position partially in welding zone with identifiable undercutting at the upper side; welding conditions: current intensity: 1,380 A, welding time: 200 ms, lift: 2.7 mm, shielding gas: M20 – ArC – 10 (Figures: Soyer (1b, 2, 3), SLV Munich)

carried out without SRM magnetic field but for the rest identical welding parameters, shows an incomplete bead formation at the upper side. With this welding, the bending test is not passed. At the break position in the welding zone, you can see undercutting at the upper side.

The SRM welding process distinguishes itself by good repeatability of the welding results which is particularly due to the little blow effect. This could be confirmed by means of tests with partially unilateral ground connection. So the SRM stud welding can – with regard to process reliability – at least be used on the same level as established stud welding procedures. First users from vehicle construction confirm the outstanding process reliability of this technology.

Permanently advanced technology

With good repeatability for M12 and M16 steel studs made of unalloyed and alloyed materials being suitable for stud welding, the SRM welding procedure satisfies the acceptance criteria of DIN EN ISO 14555 even with extensive quality requirements. This could be proven by means of corresponding bending and tensile tests as well as using metallographic examinations.

Due to the low-energy concept, the SRM stud welding connections distinguish themselves by very even bead and weld penetration shapes. The radial-symmetric magnetic field effectively protects the arc from blow effects, also during out-of-position welding. The shielding gases pure argon and argon with up to 18% CO_2 share are suitable for stud welding with the SRM procedure up to M16 (unalloyed steel). The SRM procedure requires an effective magnetic field shielding gas fixture as well as careful adjustment of the welding parameters to the boundary conditions.

The device extension is in many cases possible even with existing welding inverters. At the welding guns and/or welding heads, the necessary shielding gas field creating unit is attached to the existing support equipment without problems.

The SRM technology as innovation of stud welding, which already received numerous awards, is continuously advanced. Apart from the potential of welding larger stud diameters, research is currently focussing on questions regarding the carrying capacity under fatigue load with cyclic loading and thus regarding vibration resistance.

One part of the results explained in the contribution was determined within the frame of a current research and development study regarding SRM stud welding which is promoted by Bayerische Forschungsstiftung (Bavarian Research Foundation), Munich.

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