

New Developments in High-Performance Arc Welding Processes

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1. Introduction

There is an increasing demand in welding processes, which guarantee an excellent welding quality, an increase in productivity and a reduction of costs at the same time. This demand leads to the development of high-performance welding processes with increased deposition rate, which are defined by a deposition rate higher than 8 kg/h. Customers want to convert the higher deposition rate either into a higher cross section of the weld seam or into a higher welding speed. With modern high-performance welding methods the deposition rate / welding speed can be increased approximately by a factor of three.

2. Welding equipment

For high-performance welding it is not sufficient that the power supply delivers a high current, but the whole equipment has to be adapted properly. In the following the power supplies and the wire feeders are described in detail. The torches will be presented in the chapters about applications. In this chapter about technology also a new torch cleaner is presented and its advantages are described.

Generally Fronius offers complete welding systems with a modular structure. Fronius systems are very robust and offer "plug and weld" in manual systems as well as in fully automated systems.

2.a. Power supply

In the new Fronius power supplies for high-performance welding the principle of power sharing is employed. Power sharing describes the use of more than one (preferably two) power supplies to increase the welding current and / or the duty cycle. Another advantage of power sharing is that the two power supplies can be disconnected and used as separate standard power supplies when high-performance welding is not necessary. There are two possibilities in power sharing:

- Both power supplies act together in one single arc (single-wire welding).
- The power supplies act in two arcs (tandem welding).

Both in single-wire and tandem welding power sharing requires a rapid data exchange between the two power supplies to synchronize them. Fronius solved this problem with a Local High Speed Bus, which exchanges data by a rate of 10 Mbits per second.

Fig. 1 shows the TPS 9000, which is formed by two TPS 5000 and delivers a welding current up to 900 A together with a schematic drawing.

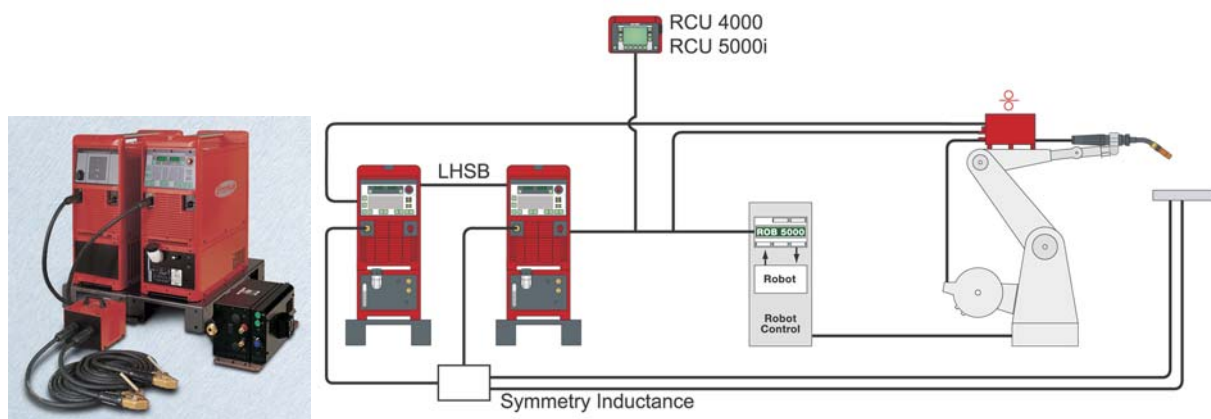


Fig. 1: High-performance power supply TPS 9000 which delivers a welding current up to 900 A.

2.b. Wire feeder

High-performance welding is characterized by high welding current and / or high wire feed speed. Therefore not only the power supply has to be changed to fulfill the requirements, but also the wire feeder has to be adapted for high currents and high wire feed speeds. Fronius has a wide range of wire feeders which are used for high-performance welding and which show different special features. Table 1 summarizes the different wire feeders and their special fields of application.

Wire feed unit	VR 1500 11	VR 1500 12	VR 1500 30	VR 1500 22
Wire diameter	0.8 – 3.2 mm	0.8 – 3.2 mm	0.8 – 1.6 mm	0.8 – 1.6 mm
Wire feed speed	0.5 – 11 m/min	0.5 – 12 m/min	0.5 – 30 m/min	0.5 – 22 m/min
Application	Thick wires	Thick wires, high torque	High wire feed speed	Standard

Table 1: Wire feeders for high-performance welding with their features and fields of application.

2.c. Torch cleaner

High-performance welding is commonly used in automated systems. Each automated system should be completed by a torch cleaner to remove spatters in early state and to prevent system shutdown.

Conventional torch cleaners remove spatters by milling and therefore deteriorate gas nozzle, contact tube and nozzle stock. Besides new spatters stick perfectly on already milled areas. The new Robacta Touchless Cleaner by Fronius cleans torches without touching by an electromagnetic pulse and therefore prevents damage to gas nozzle etc. The cleaning process takes place in two steps: In a first step the torch is dipped into a cooling liquid to produce thermal stress and to degrade further sticking of spatters. In a second step the spatters are removed by an electromagnetic pulse. Due to this principle of operation the Robacta Touchless Cleaner is restricted to ferromagnetic applications and can not be applied for Aluminum and its alloys.

Fig. 2 shows the principle of the Robacta Touchless Cleaner. Also a spatter ring removed from a torch is shown.

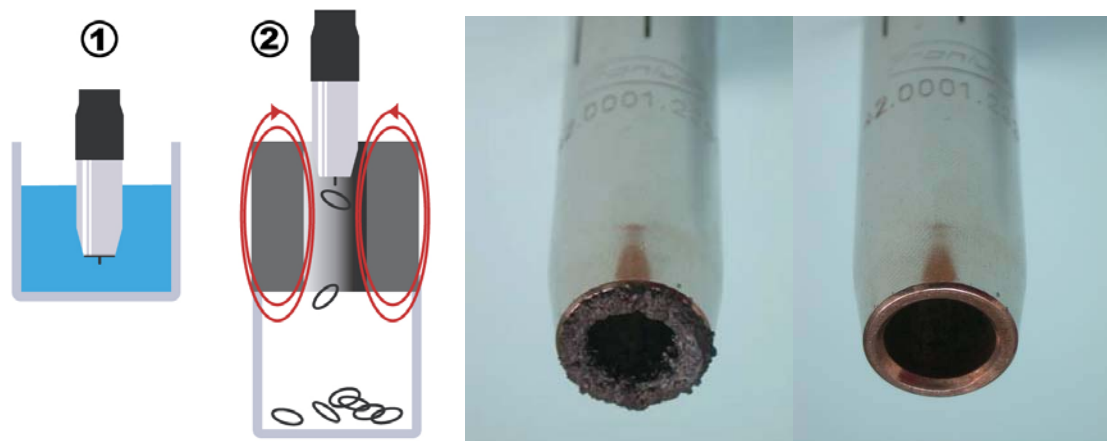


Fig. 2: Principle of Robacta Touchless Cleaner and removed spatter ring.

3. Applications

The first step to high-performance welding is an increase of the wire feed speed in single-wire welding. The next step is the development of tandem welding (welding with two wire electrodes deposited at the same time). While single-wire welding with high wire feed speed bears the problem of cutting, the torch positioning of tandem welding of non-linear profiles is difficult, as the relative position of the two wire electrodes and the welding direction must be held constant. A further possibility to increase the deposition rate is the use of strip-wires, resulting in deposition rates up to 11 kg/h. The main advantage of strip-wire welding compared to tandem welding is the single power supply and the easier handling.

High performance welding is applied in a variety of fields, e.g. automotive industry, heavy steel industry, railway industry etc. Both weld-joining and hard-facing processes can be performed. In the following three different applications of high-performance welding will be presented, namely strip wire welding, welding with large-diameter wires and tandem welding.

3.a. Strip wire welding

Table 2 shows the most commonly welded solid strip wires. The width of the electrodes is in the range 4.0 – 4.5 mm while the length is around 0.5 – 0.6 mm. Therefore strip wires have an extreme width-to-length ratio of approximately 1:9. Strip wires are produced either by deformation of round wires or by cutting broader bands. Generally the ratio of surface to cross-section area is larger for strip wires than for round wires and so the surface quality of the wires is even more important for the welding result.

For steel the wire feed speed can be increased up to 11 m/min, which corresponds to a deposition rate of more than 11 kg/h, while deposition rates up to 4 kg/h can be achieved for the Al-alloys.

Filler Material	G3Si1	AlMg4.5Mn	AlSi5
Cross section	4.5 x 0.5 mm	4.0 x 0.6 mm	4.0 x 0.6 mm
Cross-section area	2.3 mm ²	2.4 mm ²	2.4 mm ²
Wire feed speed	Up to 10.7 m/min	Up to 9.2 m/min	Up to 9.2 m/min
Deposition rate	Up to 11.3 kg/h	Up to 3.6 kg/h	Up to 3.6 kg/h

Table 2: Most commonly welded solid strip wires and welding parameters.

The torch used in strip wire welding is a Push-Pull torch which has been further developed for this application (Fig. 3). The contact tube has a rectangular opening to guide the wire in both horizontal and vertical direction. The gas nozzle is water-cooled to the very tip, which is especially important for high welding currents.

Due to the difficulties in wire feeding arising from the rectangular shape of the wires, strip wire welding is preferably used with sample handling or for long linear seams, where the torch is moved on a linear drive.

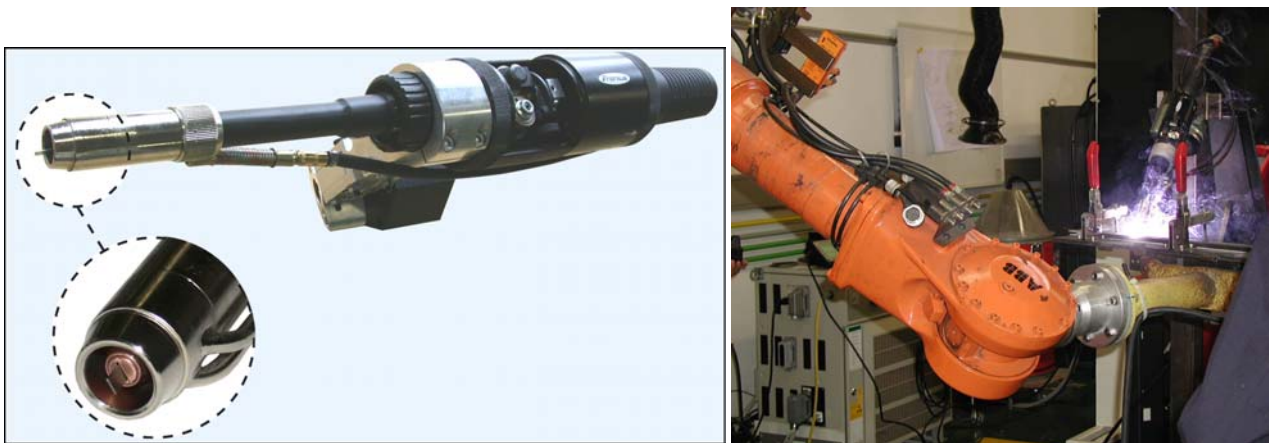


Fig. 3: Push-Pull torch for strip wire welding and application with sample handling robot.

Figure 4 shows the material transition of strip wire welding in case of a pulsed arc. Pictures are taken both from the long and from the short edge of the wire. It is important to mention that the arc burns stable on the whole edge of the strip wire the whole time. Besides, the arc has a pronounced elliptic shape at the strip wire but becomes almost round at the sample to be welded. Also the droplets which are detached from the wire are approximately spherical, which can be attributed to surface tension.

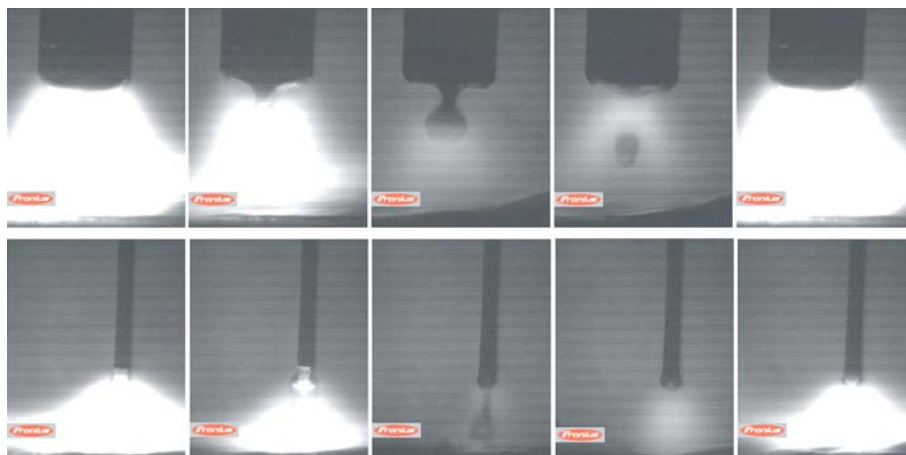


Fig. 4: Material transition of the AlSi5 strip wire (wire feed speed 5 m/min).
View from the long and from the short edge of the wire.

Investigations of penetration were also performed. The penetration of strip wire welding was compared to the penetration of round wires with 1.6 mm diameter, as these wires have similar cross-section areas. As a result it was found that the penetration of strip wires is much less than the penetration of round wires. Besides the penetration of strip wire welding is almost independent from the angle between long edge of the strip wire and welding direction. The smaller penetration of strip wires compared to round wires makes strip wire welding preferable for hard-facing processes. Experiments with Ni-based strip wires were already performed and showed good results.

The increase in deposition rate in high-performance welding can either be transformed into a higher welding speed, which is the goal in most cases, or into a larger cross-section of the weld seam. Fig. 5 shows overlap seams of 3 mm sheets with different filler materials. When comparing these welding speeds with standard round wire welding, it can be seen that the welding speed with strip wires can be strongly increased compared to standard round wires. The heat input into the base material is also decreased for strip wire welding.

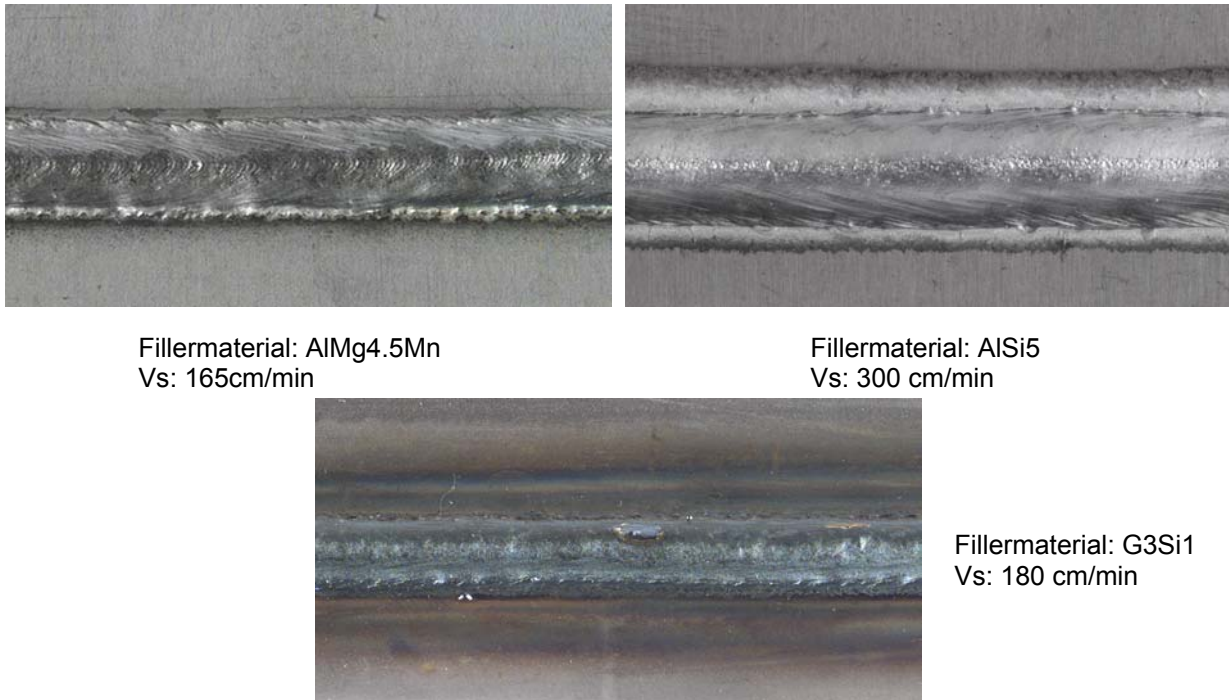


Fig. 5: Maximum wire feed speed for overlap seams of 3 mm sheets with different filler materials.

3.b. Welding with large-diameter wires

In standard single-wire welding the wire feed speed can not be increased endlessly, as at a certain point the problem of cutting occurs. For further increase of the deposition rate in single-wire welding it is possible to maintain round wires, but to increase the diameter of the wires up to 3.2 mm. These wires are available in all common materials (Al, Al-alloys, steel, copper-base wires, flux-cored wires, ...) and are usually welded in PA or PB position. The main disadvantage of these wires is the wire feeding: Very soft wires such as Al are difficult to feed as they lack form stability. On the other hand hard wires such as steel also have feeding problems as these wires are very stiff, when the diameter is very large.

Fig. 6 shows experiments which have been performed with a 2.4 mm flux cored wire. The wire feed speed was set to 12 m/min and therefore a deposition rate of 25.5 kg/h was obtained.

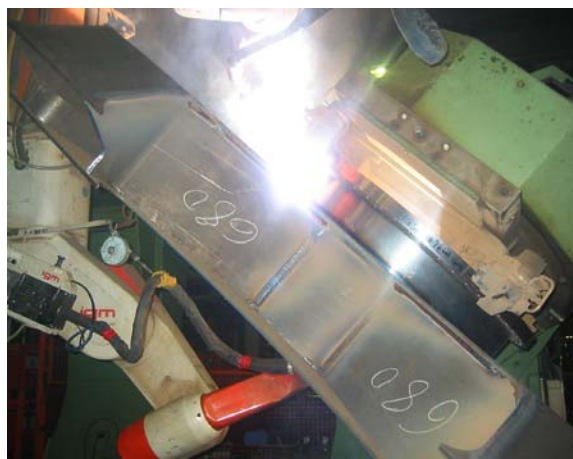


Fig. 6: High-performance welding with a 2.4 mm flux cored wire (deposition rate 25.5 kg/h).

Due to welding with large-diameter wires deposition rates can be strongly increased. It is possible to weld fillet joints with a large throat thickness in one single pass, while it takes two or more passes with conventional wires. Therefore cycle time can evidently be decreased and productivity increased.

3.c. Tandem welding

The main difference between tandem welding and double wire welding is the fact that in tandem welding the contact tubes of the two wires are electrically isolated so that the two electrodes can have different electrical potential. Therefore arc mode (standard, pulsed), arc length, current, power etc. can be adjusted separately for both arcs. Also the material transition of both arcs can be influenced and optimized separately. In many cases both electrodes act in a pulsed arc with the material transitions shifted by 180°, which means that one wire has base current while the other wire has pulse current and vice versa.

Fig. 7 shows the torch Robacta Drive Twin, which is a Push-Pull torch. On the right side of the picture the electrical separation of the contact tubes can be clearly seen. Due to the Fronius technology both welding directions are possible, so that master and slave can change. Therefore cycle time can be further decreased.

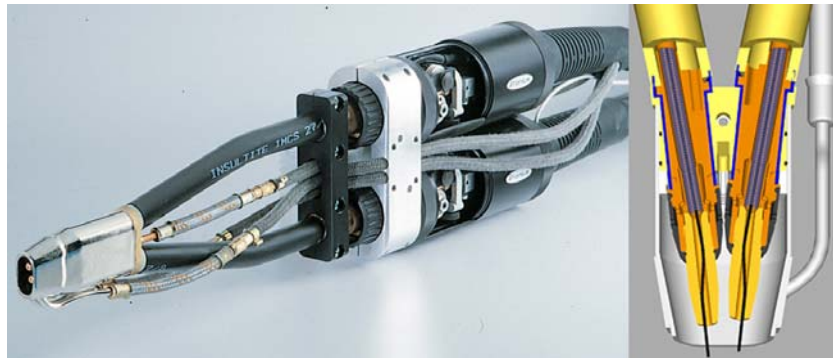


Fig. 7: Robacta Drive Twin Push-Pull torch for tandem welding – overview and detail.

The main advantages of tandem welding are high welding speed, little spatters and high flexibility. Tandem welding can be performed with a variety of filler materials. Fig. 8 shows tandem welding of a stainless steel boiler with a CrNi filler wire. The sheet thickness is 5 mm and the welding speed 240 cm/min. In this case two torches work on both sides of the cooling tubes at the same time and each torch follows a tactile sensor for seam tracking.

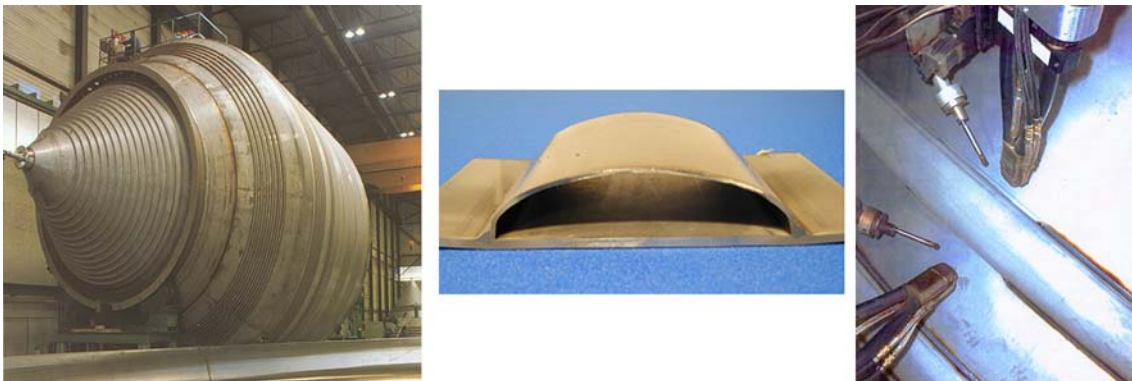


Fig. 8: Tandem welding of stainless steel boiler with CrNi filler wire.

4. Conclusions

In this paper different possibilities of high-performance welding were presented. The first step is an increase in the wire feed speed in conventional single-wire welding. The next step is an increase in the wire cross-section area, either by increasing the diameter of the wire up to 3.2 mm or by using strip wires with a rectangular shape. Another way to increase deposition rate is to melt more than one wire electrode at the same time as it is done in tandem welding.

While conventional single-wire welding with high wire feed speed bears the problem of cutting, the torch positioning of tandem welding of non-linear profiles is difficult, as the relative position of the two wire electrodes and the welding direction must be held constant. The main advantage of strip-wire welding compared to tandem welding is the single power supply and the easier handling.