Progress In MIG/MAG-Welding With The Help Of Modern Multi-Process Welding Power Sources

Dipl.-Ing. D. Dzelnitzki, Mündersbach

1 Introduction

Today, developing modern welding power sources does not only mean to react to the requirements of the welding-related market, but also to develop forward-looking technologies independently and to offer them practically.

Welding is one of the most demanding fabrication processes. The combination of the different fields, reaching from material and process engineering to electrical engineering, entails very complex problems that each of these fields has to face.

Traditionally, we relied on specialised power sources when using different welding techniques. But the ever more quickly changing needs of the market and its products require flexible fabrication processes, which can be realised very easily with the help of multi-process welding power sources. The growing competition forces us to keep the cost for buying capital goods on a moderate level. Of course, the product “weld” has to meet fixed quality requirements. What becomes the decisive criterion is fulfilling this task as efficiently as possible and at high qualities.

2 Characteristics of multi-process welding power sources

2.1 Requirements

Different and new materials have to be processed at smaller lot sizes. A combination of different welding processes can be realised, e.g. TIG or MMA root welding, MIG/MAG interpass and cover pass. Another area of application is coupling with high-performance processes such as laser welding. By combining process variants, for example
- laser and plasma,
- laser and MIG/MAG,
- laser and TIG,
power and quality increases can be achieved with already existing laser welding devices.

2.2 Working principle

The possibility to realise different welding processes with one power source makes high demands on technology. Here, three components constitute the basis of this system:
- the power module,
- the control module,
- the torch-connection module.

In recent years, the inverter has become the most important power module, the “heart” of the power source. Advantages of this principle are the relatively small dimensions, the high efficiency, the insensitivity towards mains voltage fluctuations and, in consequence, the very good reproducibility of the welding parameters. The “brain” of the power source - the control unit - must be able to switch different static load characteristics together with the power module, such as
- constant-current characteristic for MMA, TIG and plasma welding,
- constant-voltage characteristic for MIG/MAG welding.

Furthermore, the control unit stores the given welding parameters. Of course, the system consisting of inverter and control unit also determines the ability of the arc to react very quickly to different influences in order to keep the parameters on a constant level, irrespective of the cable length in the welding circuit. But above all, the control unit is that part of the power source that enables humans to manage this system. Easy handling is possible because of the dialogue between display (multilingual) and controls, Fig. 1. Ideally, only the operating elements for the respective welding process are active.

The“tool”arc is guided by the torch-connection module, the “arm”, and optimised for the respective application by the torch. This way, a compact system of independent modules develops, which form one power source by cooperating. The combination of individual elements determines the welding process.

Fig. 1. Example of a foil keyboard for MIG/MAG, MMA and TIG welding
3 Examples of use in practice

3.1 The "Integral" power-source concept

3.1.1 Power source and work ranges

The "Integral MIG/TIG 500 Puls" power source, Fig. 2, is designed for standard and pulsed MIG/MAG welding, TIG direct-current welding and MMA welding. The user arranges his or her optimal welding device consisting of the individual components.

Fig. 2. Multi-process welding power source

The integral system consists of three different power modules: 250 A/350 A/500 A (60%ED). All these modules have, however, the same control module. After selecting a power module, the user can generally choose between three operating modules that can be interchanged at any time. Each module has several jobs. These jobs are characterised by a special combination of materials, wire-electrode diameter and shielding gas.

Jobs for the area of the standard (short, semishort circuiting and spray arc) and pulsed arc are stored. All these arc types have important areas of application:

- **Short arc**
  The material transfer from the wire electrode to the workpiece takes place because of the influence of gravity and under short-circuit formation. At each droplet detachment the arc is interrupted, Fig. 3. The entailed low heat input is an advantage for welding small material thicknesses and root passes.

- **Semishort circuiting arc**
  When the welding current is increased, short circuits occur more scarcely because of a stronger repulse effect, Fig. 4.

- **Pulsed arc**
  The material transfer between wire electrode and workpiece takes place by suddenly changing the arc-force formation by pulse heterodyning of the welding current, Fig. 5. The pulsed arc can only be formed with argon or shielding gases containing a high percentage of argon (CO₂ percentage below 18%). The material transfer takes place without short circuits and almost without spattering.
The application area of the pulsed arc reaches from low- and high-alloy steels and aluminium- and nickel-based alloys to copper and its alloys.

**Spray arc**
The material transfer from the wire electrode to the workpiece takes place with a shower of small, fine droplets and without short circuits. Because of the high welding current, the accelerating forces on the relatively small droplets are so strong that the droplets are hurled onto the workpiece in any desired direction, Fig. 6.

With the help of the foil keyboard, the user calls the suitable job for his or her welding task, and the power source automatically selects the right welding parameters. To fulfill the general welding tasks including TIG and MMA, the power source has fixed programmed jobs. To solve special welding problems, the user can create welding parameters with freely-programmable jobs according to his or her requirements.

### 3.1.2 Control units

To guarantee full use as a multi-process welding device, the "PROGRESS 4" operating module has been developed. While the "PROGRESS" module, Fig. 1, has all functions of modern pulsed-welding power sources for MIG/MAG welding, such as ignition reliability by ignition voltage pulse, downslope to fill end craters and droplet detachment to achieve a sharp wire-electrode end and to guarantee reliable re-ignition, the "PROGRESS 4" module can do much more. With this module the user is able to call different working points by the torch trigger. At the example of a weldment, this ability will be explained.

To face the well-known problem of an initial lack of fusion because of quick heat dissipation, the welder starts with a high-power working point (P1). Thus the molten state of the parent material is quickly reached. With letting-go the torch trigger at this moment, the "Integral" device provides the second working point (P2) - with less power, accordingly to the material thickness. Then the power source welds under the parameters that are required for this weld. If the material thickness changes, the welder can react immediately by pushing the torch trigger. The power source then provides a third working point, adjusted to more or less power (P3). By pushing the torch trigger, the user is able to switch between these two working points during the welding process. To fill the end crater, a fourth working point is called by pushing the trigger for a while (P4), Fig. 7.
To extend the device to a full TIG direct-current source, a high-voltage igniting module must be installed. Any TIG torch can be connected to the device, and the “PROGRESS 4” operating module then provides complete control of the TIG cycle, Fig. 8.

In the case of MMA welding, the display of course allows the operator to set the hotstart current and time freely.

The wire feed also consists of different modules and can thus be adjusted to the different conditions. Concerning MIG/MAG welding, for instance, a push-pull torch, an interdrive as well as a torch with potentiometers for the power setting can be connected at any time. Additionally, the power source can operate with two wire feeds that are equipped for different processes such as steel/aluminium and that can be activated by the torch trigger.

The superPuls SP10 remote control is a particularly interesting accessory. It combines the quickness of MIG/MAG welding with the quality of TIG welding. As the wire electrode pulsates accordingly to the welding position, an optimised result can be achieved, especially in the thin-sheet range and in out-of-position welding, because of the reduced heat input, see Fig. 16 (course of welding current, voltage and wire feed).

3.1.3 Heavy-duty MAG welding

To make the power source meet the requirements of increased efficiency, the “HIGH-SPEED” wire-feed module has been developed. This way, solid and cored wires can be welded at wire-feed rates of up to 30 m/min in the MAG high-performance range. The “HIGH SPEED” process starts in the upper spray-arc ranges and continues in the lower ranges of the rotating arc, Fig. 9.

![Fig. 9. Working ranges of the arc types](image)

Although this range of the rotating arc has been known since the beginnings of MIG/MAG welding, it turned out that it can only be mastered with the help of complex power-source technology. High wire-feed rates, high current densities and the long wire stick-out put such a heavy strain on the wire electrode that the electro-magnetic forces lead the melting end of the electrode and the arc to execute a
circular rotational move at rotating speeds of approx. 800-1000 turns per second. The rotation causes a bowl-shaped, wide penetration, Fig. 10.

![Fig. 10. Transverse section of a fillet weld](image1)

"HIGH-SPEED" welding, parent material: S235JR, s = 20mm filler material: SG 2, d = 1.2mm, welding speed: 40cm/min shielding gas: 96%Ar / 4%O₂ welding current: 500A; welding voltage: 44V

What is the distinguishing mark of the rotating arc is the result: a notch-free transition between parent material and weld and a smooth weld surface. Standard two-component (e.g. 92%Ar/8%CO₂, 96%Ar/4%O₂) or multi-component gases consisting of argon, helium carbon dioxide and/or oxygen are used. The “PROGRESS 4" operating module again fulfills its task exactly with the help of the reduced starting-current and end-crater filling-current functions. But as these applications are only sensible for thicker materials, a quickly variable torch with two available equipping sets ("High-Speed" and Standard) fits into the modular concept

3.2 “AC/DC- Plasma” power-source concept

The “TIG AC/DC-P” power source represents a welding device that covers the complete range of MMA, TIG as well as plasma welding, Fig. 11.

![Fig. 11. Multi-process welding power source TIG 350 AC/DC-P](image2)

This power-source configuration only allows to realise several welding processes by connecting different torches. Equipped with a polarity switch, the electrode polarity can easily be switched or alternating-current operation can be chosen. Low- and high-alloy steels, exotic metals and aluminium-based alloys can be welded. The power module has three steps: 250 A/350 A/450 A (60% ED). In this case, the power source is again completed with a control and operating module that has all required operating functions, Fig. 12.

What attracts the attention is the availability of plasma welding at the negative pole for aluminium-based alloys. Certainly, there are many advantages of alternating-current welding because of its easier handling and the lower electrode load. But the possibility to use the plasma process at the positive pole just by exchanging the torch gives the advantages of this - unfortunately somewhat neglected - process new importance. A constricted arc with a very good cleaning effect produces high external weld quality. The increase in the welding speed in the thin-sheet range at extremely reduced noise pollution must be underlined. By exchanging the torch equipment plasma welding at the negative pole can be applied very easy as well. This power-source concept is completed by several remote control units, hotstart for MMA, pulsed or foot-operated remote control, for instance.
4 Connection of information-processing systems

4.1 Interfaces

Today, a quickly-developing automation technology makes utilizing industrial roboter systems even in the production of mini-series profitable. Here, in particular, far-reaching availability of the roboter - welding-device system is required. The multi-process welding power sources - equipped with an interface - can be used for several welding processes just by exchanging the respective torch connection modules. So, buying an automation system is not only related to the product that is actually fabricated, but makes it also possible to execute different welding processes in the best way possible with the same equipment in the future.

4.2 Welding-data documentation

4.2.1 The EWM Q-DOC 9000 welding-data documentation software

It is the aim of welding to put joints of highly-developed materials into practice whose features correspond to the features of the parent material. As subsequent quality and product tests cannot prove sufficiently that the welds meet the required quality standards, confidence-building measures must be taken between supplier and client referring to tightened product liability. Of course, this entails that the multi-process power-source systems have to guarantee the welding-data documentation at all times. The EWM Q-DOC 9000 welding-data documentation system fulfills this task and meets the requirements of DIN EN ISO 9000 and the following standards.

4.2.2 System requirements

The EWM Q-DOC 9000 welding-data documentation software makes minimal demands on PC systems:
- Windows 3.1,
- PC 386DX, 40 Mhz,
- 4 MB memory space

4.2.3 Working principle

Measuring sensors inside the power source record the actual values of welding current, voltage, wire-feed rate and armature current of the wire-feed motor and transmit these data via interface to the PC. The welding data are represented in an online bar graph during the welding process and can be stored and analysed after the end of the process. With a connected printer the desired measuring report can be printed out at any time, Fig. 13.
One hour of recorded welding data only takes up 0.25 MB memory space. In order to be able to reproduce the welding process for recurring welding tasks or later liability cases, a detailed description of all process-related parameters is necessary. Among the head data are general information concerning date, time, client, constructional drawing and welder. Via a selection menu the whole welding task is described (e.g. welding process, parent materials, filler metals and shielding gases), Fig. 14.
During the welding process, all actual values can be monitored permanently, Fig. 15. If tolerances that have been fixed by the welder are exceeded, this is shown on the screen: the bar of the respective parameter turns red.

The measured parameters can be analysed in a graphical representation as a function of time, Fig. 16. The absolute values of each parameter can be called for any point of time. Reference welds and tolerance divergences can be put on the screen.

Fig. 15. Online weld

Fig. 16. Graphical representation of the welding parameters
4.2.4 Areas of application of the EWM Q-DOC 9000 software

Practical application in
- gas-shielded metal arc welding,
- tungsten-inert gas welding,
- plasma welding and
- manual metal arc welding
as
- a means of quality control in welding production,
- an instrument for drawing-up and documenting welding instructions (WPS),
- a supporting means for welding-process checks and their documentation,
- a means of post-calculation of the welding production,
- an important instrument in welder training.

5 Prospects

In the future, multi-process welding power sources will develop into a centre of interest in welding-related production.
In consequence, the manufacturers will have to offer modular power-source systems. The user can configure his or her welding device by arranging and composing the individual modules, the device can be updated with software modules and extended at any time. There, torch systems will be useful that have connections that can be used variably.
An example of today will show this trend. The interesting TIG direct-current welding technology with high-frequency pulses is realised via a standard power unit; an additional module with a remote control enables the system to pulse the welding current up to 8 kHz. The purpose of this process is to increase the welding speed of TIG welding in automatic fabrication. The arc and the molten bath are stabilised with this method and cause a concentrated penetration, Fig. 17.
This shows that - to turn such a technology successfully into practice - the intense integration of power-source technology, on the one hand, and process engineering, on the other hand, is required. The multi-process welding power source is an important element of such a concept.

Fig. 17 Transverse section of a butt weld, TIG welding, parent material: 1.4301, s = 2 mm, no filler material, welding speed: 2.7 m/min