Challenges and benefits of dynamic power source adjustment for MIG/MAG welding

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High-quality operating concepts enable the user to adjust dynamic properties of the welding power source for MIG/MAG standard welding processes. The article is thematically concerned with which parameters can be summarized under the term "dynamic" for modern inverter power sources and which process engineering effects arise thereby. The technological and practical benefits are considered.

1 Technical Background

The electrical behaviour of welding power sources can be described in terms of static characteristics for slow load changes. The static characteristics represent the correlation of the welding current and arc voltage in a single current-voltage diagramme (C-V curve). Traditional continuously switched power sources with transformer have as many static characteristics as there are available different levels (steps); **Figure 1**.
The respective static characteristic curve is selected by step (S) and described by the physical variables no-load voltage U_0 and short-circuit current I_K, or characteristic slope du / di.

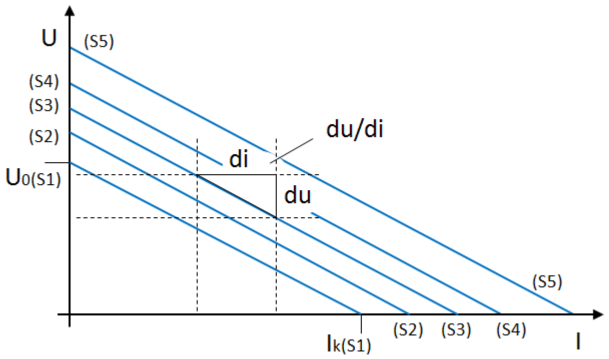

Figure 1: Schematic representation of the static C-V characteristics of a traditional step switched welding power source. S1..S5 = levels

The arc welding process itself has a load characteristic (LK) that results from a variety of physical interactions. Together with the set static characteristics of the welding power source, the result is a common average operating point (AP); **Figure 2**.

The exact location of the average operating point on the static characteristic curve is influenced by the arc welding process itself, most strongly by the wire feed speed.

Since each arc welding process always has a certain change in the arc length, whereby a short-circuit is the most extreme result of an arc length change to zero, the actual operating point more or less regularly moves around the average operating point in the C-V diagramme.

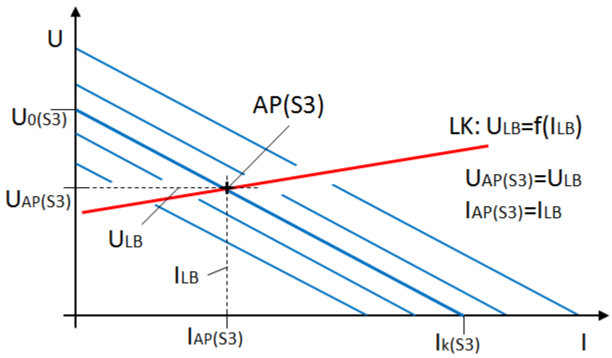

Figure 2: Schematic representation of the formation of a common operating point (AP) as the intersection of the set static characteristic of the welding power source (in this example S3) with the static load characteristic curve (LK) of the arc.

The inductance (choke) deliberately introduced into the welding circuit for MIG/MAG welding allows the arc, or the short-circuit, to leave the static characteristic of welding power source for a short time, **Figure 3**, by briefly loading extra energy in its magnetic field, to be released again later.

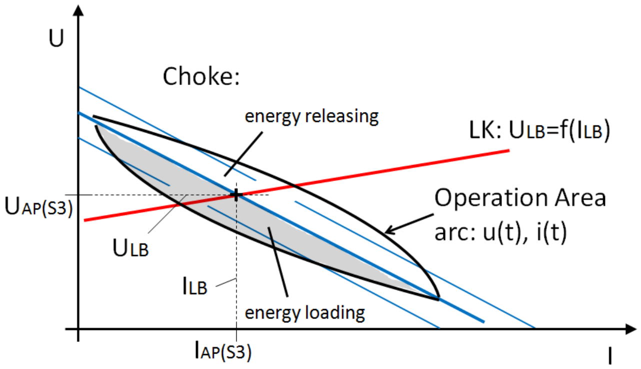

Figure 3: Schematic representation of the effect of a choke in the expansion of a static operating point from welding power source and static load characteristic to a dynamic operation area of a short-circuit-free arc welding process

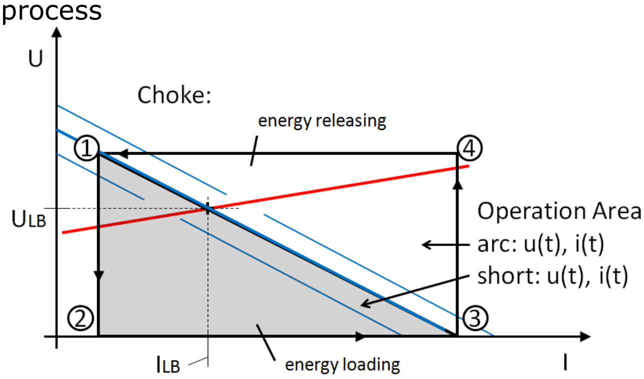

Figure 4: Schematic representation of the effect of a choke in the expansion of a static operating point from welding power source and static load characteristic to a dynamic operation area of an idealized short-circuited arc process; the arrows indicate the direction of the operating point movements.

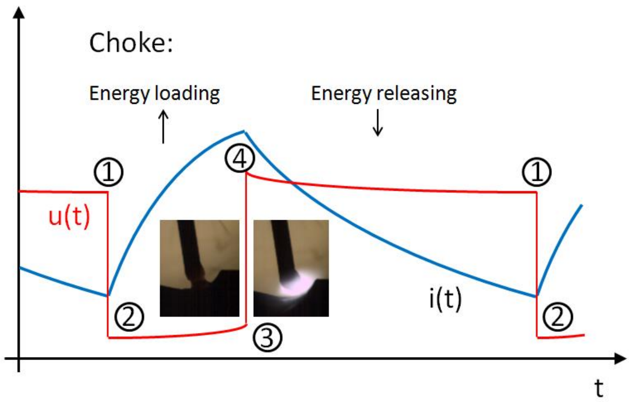

Figure 5: Effect of the choke in the temporal waveform of welding voltage u(t) and welding current i(t) of a non-idealized process with short-circuited material transfer; with respect to the operating point identification in Figure 4.

The increase or decrease of the flowing current is attenuated by the choke, and the greater the choke (the physical value of the inductance) the stronger the attenuating. This is done symmetrically, that is, the additional loaded energy is completely released later on.

The brief movements of the operating point made possible in this way are designated as dynamic operating point movements. Particularly evident is the interaction of the static and dynamic properties of the welding power source with the welding process in the case of short-circuited material transitions, **Figure 4, Figure 5**. Proper welding requires the proper coordination of all elements: the temporal course of the current increase during the short-circuit and current reduction in the arc phase, the average values of welding voltage and welding current over short-circuit and arc phases and, of course, the wire feed speed.

The process influencing characteristics of a traditional welding power source can, therefore, be described solely by the adjustable static characteristics and the dynamic action of the choke. The multi-stage selection of choke properties is associated in the case of traditional welding power sources with appreciable effort, which is why - if at all - only a few choke stages are common; **Figure 6.** Therefore, the adaptability of conventional welding power sources is limited to various application conditions.

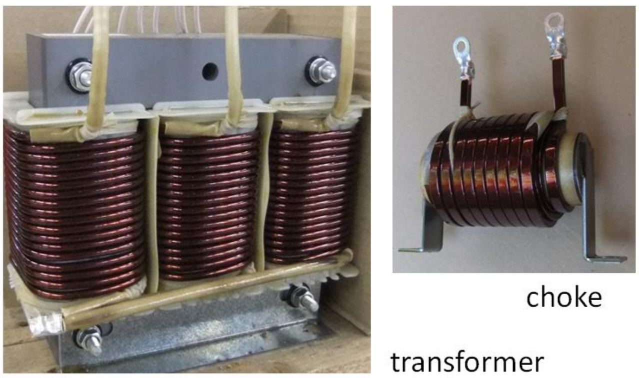

Figure 6: Step switch transformer and choke without multi-stages for MIG/MAG welding power source of average power

Electronically controlled welding power sources can replicate the described physical relationships between the static characteristic and the inductor effect. Moreover, they can break through the energetic symmetry of the conventional choke, because the choke only seemingly (virtually) exists within the control structure. In modern digital welding power sources, an almost limitless number of variations of parameters can be applied to the welding process; **Figure 7**. Thus, the process influencing properties of a conventional welding power source are not only reproduced, but also significantly improved.

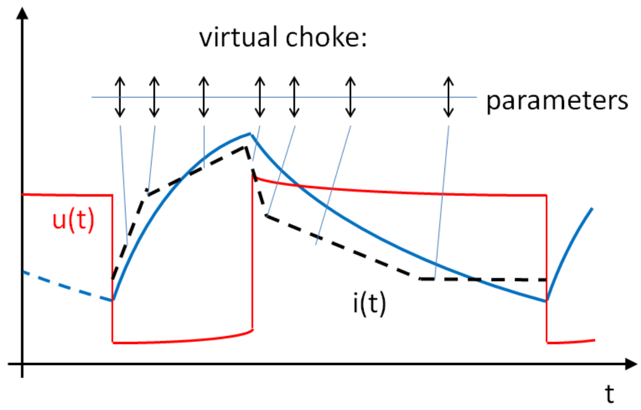

Figure 7: Example of parameters for the virtual choke of a digitally controlled welding power source

The challenge now is: how does the user easily tap into these various possibilities with simple operation?

2 Synergy Control

Figure 7 is the temporal waveform of the welding current for a MIG/MAG process with short-circuited material transfer. The arrows serve to identify the degrees of freedom provided in the control of the welding current for this example. Each of these degrees of freedom is assigned to a specific parameter, which influences by its numerical value the welding current waveform at its current level and in its course of time. All parameters must be matched in their own numerical value to each other, so as to result in the desired favourable welding process technical properties. The coordination of these many parameters is usually done by the manufacturer of the welding power source. This is costly and complex work which requires a great deal of experience and numerous welding tests. See **Figure 16**.

Once the optimal numeric values for the parameters are found for an operating point, they can also be carried out in each case for other operating points, which, for example, are adjusted by changing the wire feed speed. The combination of all these parameters with a common leading parameter, for example, the wire feed speed will then result in a synergy characteristic or a welding program.
This means that an adjustment of the leading parameter entails the simultaneous adjustment of all linked parameters, whereby the coordination of the parameters is maintained and the welding process continues without hindrance.

In the case of pulse current sources, this property of synergy controls has been the state of the art for many years and is also applicable to standard MIG/MAG welding processes. The right synergic characteristic is commonly addressed here through the pre-selection of a particular material/wire/gas combination or by entering a specific program number (synergic line).

The wire feed speed is a direct leading parameter for this purpose, because the set value represents the direct reference value for the wire feed and at the same time is the leading parameter for synergy control.

Some users desire another leading parameter, for example, the average welding current. These are then indirect leading parameters, **Figure 8**, because in the MIG/MAG process, the welding current actually adjusts as a function of the wire feed speed and welding voltage, and not vice versa. In fact, therefore, the synergy control interprets an indirect leading parameter as a prognostic value, which is measured and displayed in the welding itself, but not accurately controlled.

The average arc voltage can either be directly adjusted or corrected in terms of typical synergy controls within a certain range in order to achieve an adaptation to different application conditions.

A hidden synergy control is advantageous if the pre-selection of a particular material/wire/gas combination should not take place, for example, because the operation does not provide these choices. This is referred to as "manual mode." In this case, the stored parameter data are common to the variety of possible material/wire/gas combinations. A special feature in the setting of the Lorch MicorMig welding power source with Basic control panel is the preselection still possible between mixed gas (ArCO2) or 100% CO2.

Figure 8: Setting the indirect welding current leading parameter (left button and display) and the desired average welding voltage (right button and display) using the Lorch MicorMig with Basic control panel.

3 Dynamic adjustment

There are many reasons to change the dynamic effect of the welding process, even if the initial settings (e.g., through the synergy) already enable stable welding. The main reason is the personal assessment of the effect of the arc process by the welder, who has a direct welding task in mind. Every welder would then like an electric arc process that meets all of his demands and expectations and that he can individually set as "hard", "medium" or "soft."
For this purpose, Lorch has provided the "dynamics" setting parameter, **Figure 9**.

Figure 9: The "dynamics" setting parameter of the Lorch MicorMig with BasicPlus control panel.

The different control panel variants offer tiered setting options; **Figure 10**.

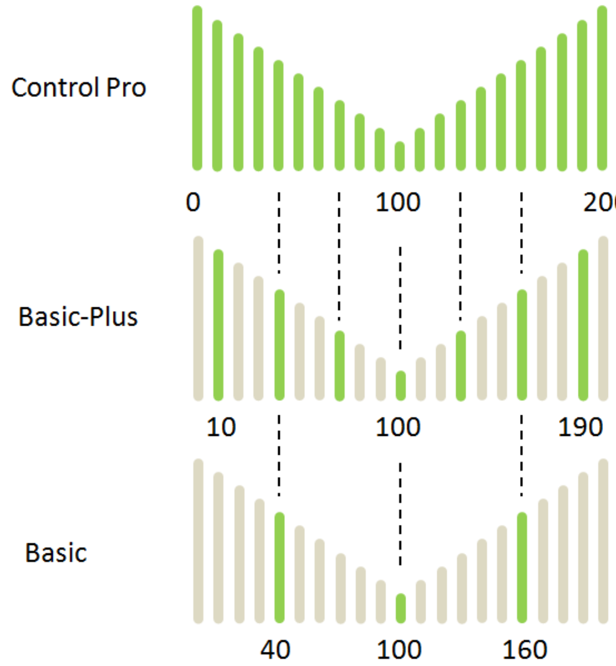

Figure 10: Different control panel types offer staggered adjustment of process dynamics

The main task of the "dynamics" setting parameter is the adjustment of the arc to the subjective expectation of the welder in parallel with the other settings, whether they are made through synergy or direct settings. An adjustment of "dynamics," however, should not adversely affect the parameters already coordinated for a stable process of the wire feed speed and arc voltage.

A team of experienced Lorch welders has laid the foundations for a solution within the context of practical research. What is needed is a fair and gradual adjustment of several different additional parameters which define the course of the welding process according to **Figure 7** and are generally of synergistic origin. Dynamic adjustment of this nature is possible for both a comfortable synergy control as well as a manual setting with hidden synergy. Required, so to speak, is a "dynamics" synergy within a characteristics synergy.

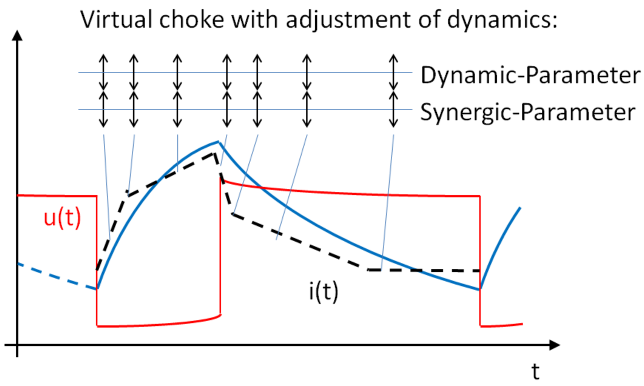

Figure 11: Example of parameters for the virtual choke of a digitally controlled welding power source with additional options for adjusting the dynamics

These additional gradual adjustment options are indicated in **Figure 11** on the example of the selected current waveform for the short arc.

A change to the welder's subjective assessment of the arc effect as "hard" or "soft" simultaneously changes the subjective effect with regard to "cold" or "hot," because these effects are related.

The consistent implementation of this change in the arc effect at a constant wire feed speed thus also requires changes to the arc voltage and the average welding current. So that changes to the "dynamics" setting produce the desired arc effect on the one hand and the process remains stable and low-spatter with an unchanged wire feed speed on the other hand, the control automatically changes to some extent the welding voltage.
The main setting and correction option for the welding voltage still occur, however, by way of the directly provided operating parameters, i.e. right button and display; **Figure 8**.

4 Process engineering effect

The beginning of the welding process is a especially challenging in terms of process engineering, because the liquid melt must be formed from the still solid material. With conventional power sources, the choke can be made "harder" with additional electronics to support the start of welding (e.g., by shorted coil), however, a useful increase in arc voltage cannot occur in this fashion.
The dynamic power source adjustment described for the modern digitally controlled power source now offers ample options that can be used for the start of welding. **Figure 12** shows image sequences of a welding process in which a programmed short-term voltage addition facilitates the quick formation of a melt. Of course, the user can change or disable the effect of this function.

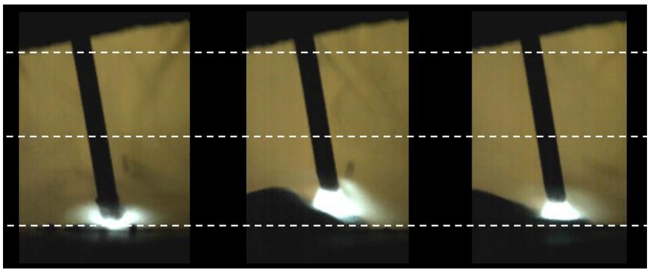

Figure 12: Start of a welding process with "hot start."

- Left: Initial ignition of the arc through highly dynamic upslope
- Centre: Forced formation of the melt pool with increased arc voltage and adapted dynamics
- Right: Stabilized arc welding process for the actual weld after start-up

Over the general course of welding, the selected and suitable means of remote control also affect adjustable current power source dynamics during welding.
The effect of differently set power source dynamics can be felt, especially with short-circuited material transitions in the short arc range and also in the transition arc. **Figure 13** shows the fundamental process engineering effect of the "dynamics" parameter.

An adjustment of "dynamics" to the left, to lower values, results in a "softer" arc, connected to more voltage and more thermal energy. The arc becomes larger, wider, brighter, and the melt more malleable.
This type of arc, for instance, is very suitable for root welding V seams, or for concave fillet welds with a flat edge connection, as well as workpieces with strong heat dissipation. This "soft" arc is also especially low-spatter in some applications.

The adjustment of "dynamics" to the right, to higher values, results in a "harder" arc, con-

nected to less voltage and less thermal energy. The arc is more concentrated, narrow, powerful.
This type of arc, for instance, is very suitable for welding intentionally vaulted corner welds or for thin workpieces with minimal heat dissipation.

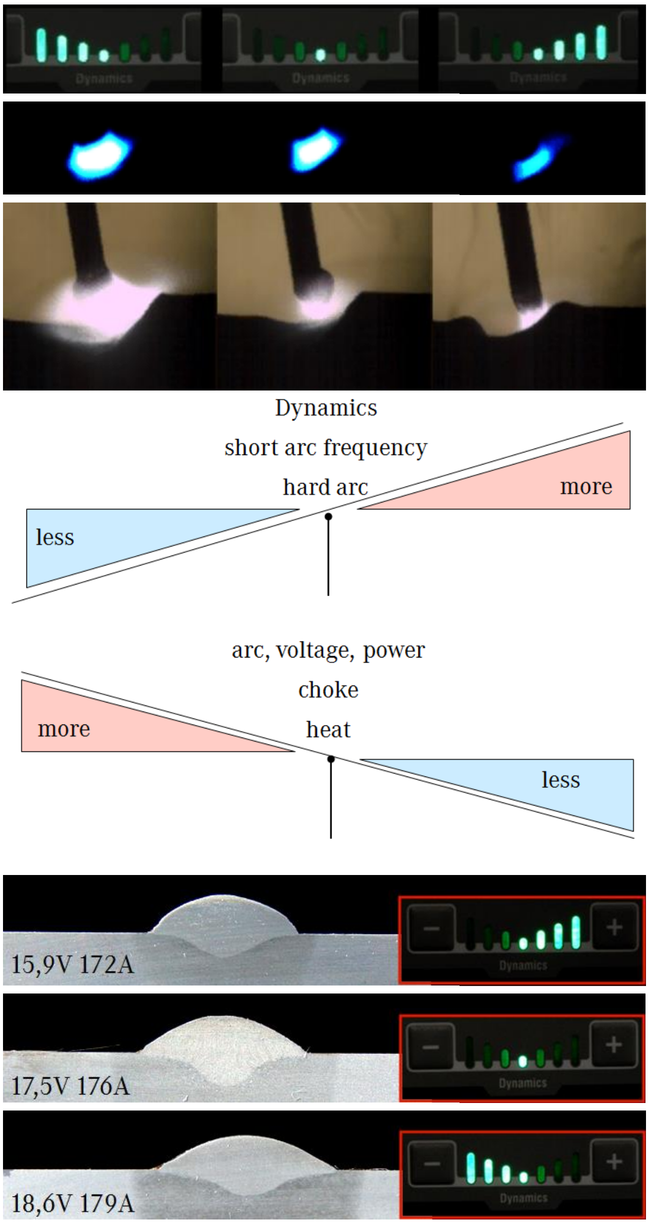

Figure 13: Effects of the "dynamics" adjusting parameter
Setting for the three polished specimens: 1.2 mm G3Si1, 4 mm S355, Vd 4.5 m/min, Vs 20 cm/min, 17 mm Stickout, MW5500, 33.5 mm contact tip, 14 mm gas nozzle, 2 mm protrusion, torch angle 7° forehand.

5 Dynamic adjustment of the torch

Assignments in the practice of manual welding repeatedly occur where changes to the peripheral conditions occur in the seam contour. These may be changing clearances, web widths, seam angles, seam positions, tack welds or other changes.
If the welder uses a PowerMaster torch, then it can be adjusted during welding to the "dynamics" parameters, **Figure 14**. Due to the special programming, the arc process always remains stable. The welder can now take advantage of the process engineering effect of the dynamic adjustment in order to respond to the changes in the seam conditions.

Figure 14: Adjusting the "dynamics" parameter at the torch. This is also possible during welding.

6 Application notes

Basically, all general and known application recommendations for MIG welding apply for modern welding power sources with dynamic power source adjustment, as well as for the welding accessories.

As demonstrated in the previous Section 4, "Process engineering effect," the current dynamic power source adjustment now offers the user the properties of different welding power sources, i.e. "hard"/"medium"/"soft" or "cold"/"hot" or "more"/"less" arc in a single machine. The user can influence the process engineering effect over the "dynamics" adjustment parameter and optimise it to the requirements of its welding task. He should also do so, because an unconscious maladjustment can also cause problems. The neutral position of "dynamics" (100%, middle) is a sensible default setting for all welding tasks and, if all goes well, will also remain so.

Because the default setting for the "virtual choke" of the process control results from the characteristic parameters (see **Figure 11**), despite the power source variant "Basic" not offering a material/wire/gas setting for the appropriate setting, the user can still shift the basic setting between argon/CO2 mixed gas and 100% CO2 process gas.

The dynamic adjustment affects the interaction of natural dynamics arising during the welding process with the dynamics of the welding power source and, thus, the arc voltage and consequently the introduced thermal energy. These depend on additional influencing factors, such as for example, the stickout length, torch angle setting, and various material and gas properties. Deviations may occur despite the control taking into account the effect of the set dynamics in the indicator values of voltage and current before welding. Therefore, the actual values of welding current and voltage must be observed, in particular, when making critical welds with a narrow process window.

To calculate energy and heat inputs, as in other modern arc welding processes, the product used in many definitions and formulas $U \times I$ should not be used thoughtlessly. Without hesitation, it is applicable for "conventional" MIG welding processes with unregulated power sources or processes with limited power dynamics, such as the spray arc method. For very high demands, the direct measurement of t8/5 times is highly recommended.

7 Useful limitation of parameters

The expansion of the possible process engineering effects of the power sources can raise the question of how to work in connection with welding instructions. On the one hand, an optimal adjustment of the dynamics of the power source to the welding task is advantageous; on the other hand, the welder may, as a result of this additional degree of freedom, unknowingly deviate from the permissible range of values of a specific welding instruction. The solution to this dilemma is an intentional limitation of the adjustment range of pre-optimised operating parameters.

Lorch has developed a user authorization system, which with contactless readable user authorization cards enables concrete restrictions of the operating parameters of the power source. Thus, a corresponding authorized operator can freely set the desired dynamics and voltage correction of the power source. The welder, who is limited to operate according to narrow process related parameters can, with an appropriate authorization level, adjust the parameter in a well defined area.

WPS booklets with EN1090 certified welding procedure qualifications for execution classes I and II are available for the MicorMig Basic-Plus and Control Pro power sources in synergy mode. These welding procedure tests are all welded with a dynamic setting of 100% and without voltage correction. The authorization card for the "WPS Welder Basic" user type now allows, for example, a correction of +/- 10 for the voltage and +/- 30% for the dynamics, **Figure 15**. This ensures that the tested parameter range of the welding power source is not accidentally abandoned.

Figure 15: Realisation of a beneficial limitation of operating parameters through the user authorization concept.

8 Summary

Modern inverter power sources for standard MIG/MAG welding replace not only conventional step switch transformer systems, but also offer significantly more user benefits with their advanced features and operating concepts.

The basis for this is the ability to adjust the dynamics of the process control, while maintaining a stable low-spatter process operating point by way of simultaneous synergistic voltage adjustment. The relevant technical background has been explained.

The dynamic power source adjustment for MIG/MAG welding affords the user a simple and practical means for adjusting the characteristics of the welding power source to his specific needs.

A sophisticated user authorization concept rounds out the overall benefits of the system.

Technical implementation is made possible by modern digitally controlled welding power sources, which are available on the market in the form of the MicorMig series from Lorch.

Figure 16: Optimization of characteristics and "dynamics" parameters in the welding laboratory