Effect of Inverter Power Source Characteristics on Welding Stability and Heat Affected Zone Dimensions

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Abstract. The paper presents results the research in the effect of power sources dynamic characteristics on stability of melting and electrode metal transfer to the weld pool shielded metal arc welding. It is proved that when applying inverter-type welding power sources, heat and mass transfer characteristics change, arc gap short-circuit time and drop generation time are reduced. This leads to reduction of weld pool heat content and contraction of the heat-affected zone by 36% in comparison the same parameters obtained using a diode rectifier.

Introduction

At present, manufacturers of welding equipment (including Fronius (Austria), Lincoln Electric (USA), ESAB (Sweden), UKP (Tekhnotron, Russia), VKZ (ITS, Russia), etc.) produce a wide range of shielded metal arc welding power sources. Almost all the world leaders in the field of welding production are focused primarily on designing and producing inverter welding power sources. However, production plants still use welding diode rectifiers are because they lack knowledge of the dynamic characteristics of inverter power sources.

There is a number of research works [1-7] devoted to improving stability of shielded metal arc welding. It is also important to increase efficiency of new power sources for shielded metal arc welding and to assess their influence on heat and mass transfer and on performance properties of permanent joints.

The aim of the work is to assess how dynamic properties of inverter power sources affect stability of melting and electrode metal transfer, the later being the main heat and mass transfer parameters affecting the area of a welded joint heat affected zone.

Methodology

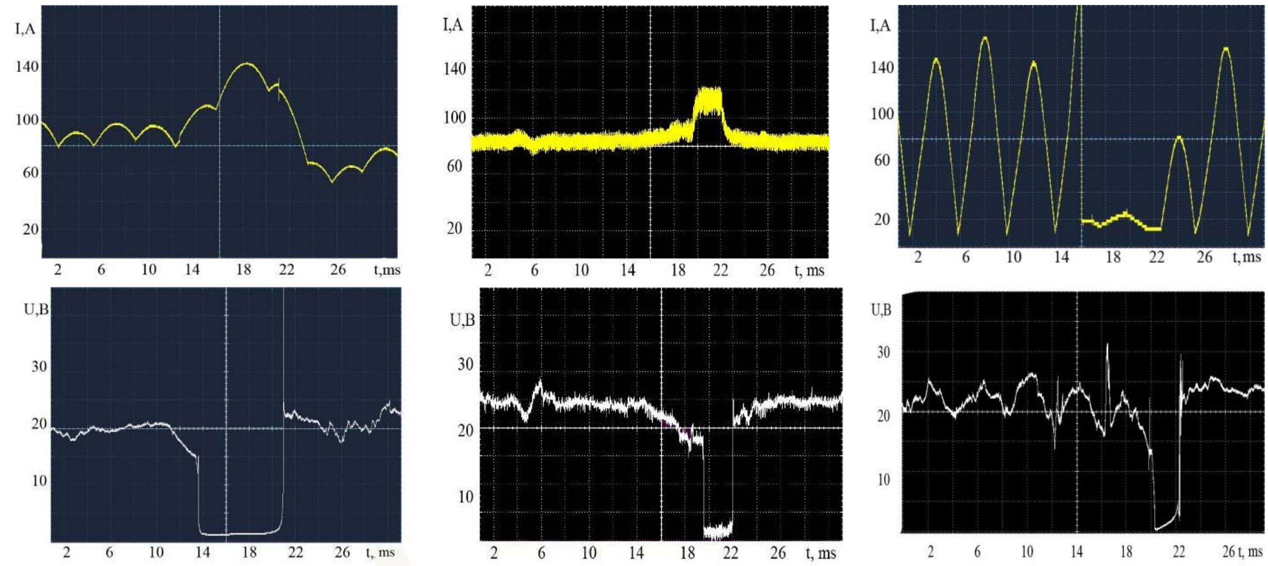
To study the characteristics of heat and mass transfer depending on dynamic properties of a power source we used an ARC-250 inverter rectifier which implements a high-frequency energy conversion method, a VD-306E diode rectifier based on the traditional energy conversion method and a VDE-160single-phase welding rectifier. We also used the most common electrodes coated with LB-52U (KOBELCO) and UONI-13/55 (ESAB). Table 1 shows surfacing conditions for test samples.

Table 1. Surfacing conditions

Rectifier type	Electrode classification	Average parameters values	Number of short circuits during surfacing
Diode	LB-52U	Current 89 ± 2.7 A Voltage 20.8 ± 0.6 V Predicted welding rate 0.25 m/min	17
Invertor			22
Single-phase			21
Diode	UONI-13/55	Current 88 ± 2.7 A Voltage 21.5 ± 0.6 V Predicted welding rate 0.29 m/min	17
Inventor			22
Single-phase			27

Results and Discussion

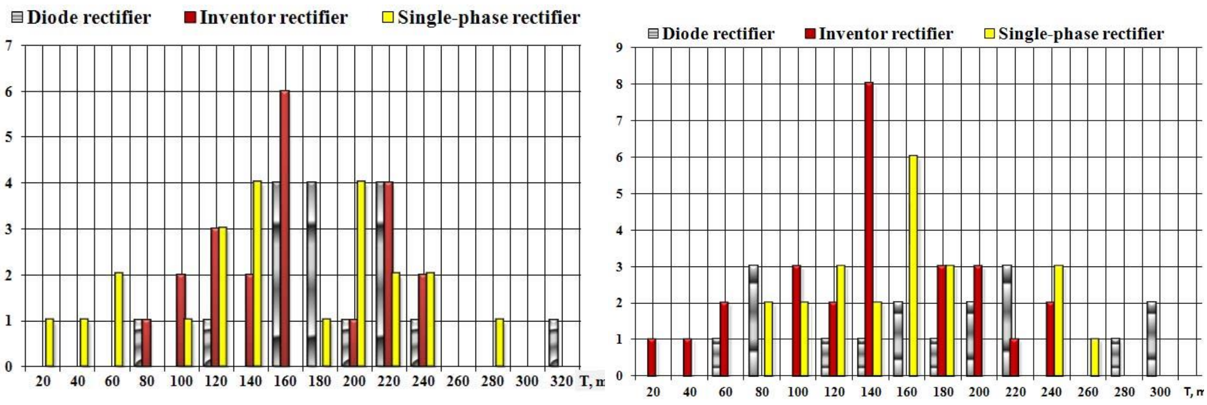
Stability of the welding process was assessed using static processing of welding current and voltage oscillograms of inverter, diode and single-phase rectifiers (Fig. 1) using the method developed earlier [7]. The results are shown as diagrams in Figures 2 and 3. The oscillograms were obtained using AKIP-4122 / 1V digital storage oscilloscope, Pintek Electronics DP-50 differential probe; PR 1030current probe remover; OWON_Oscilloscope_2.0.8.26 software.



Diode rectifier Inventor rectifier Single-phase rectifier

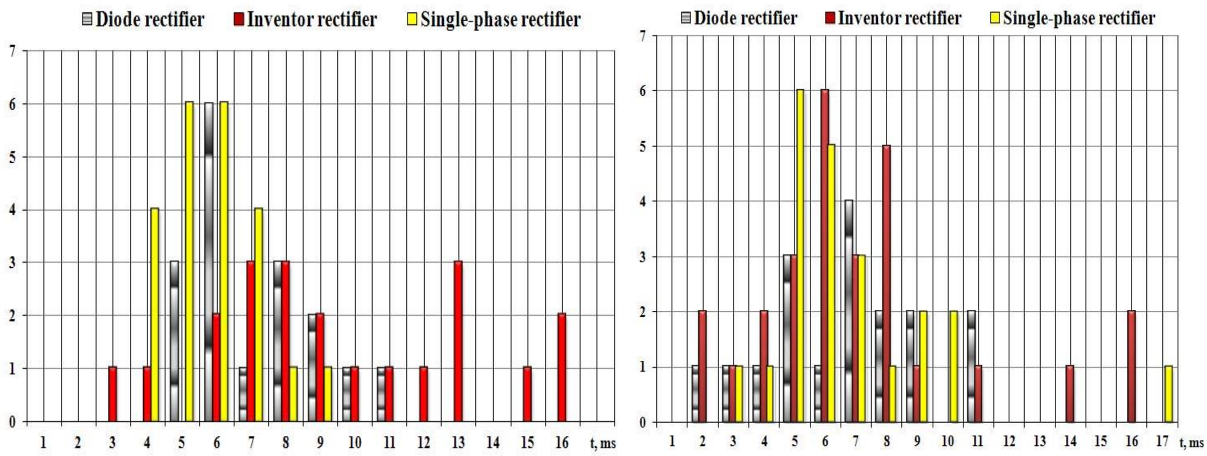
Figure 1. Oscillograms of welding circuit current and voltage between the electrode and the product, (3.2 mm in diameter LB-52U electrodes)

The experiment data analysis (Table 1 and Figure 1) shows that under identical surfacing conditions, frequency of short circuits in the arc gap increases and short circuit time shortens. It shows the advantages of the inverter rectifier before the diode and single-phase ones and may prove that the electrode metal is transferred in smaller drops.



LB-52U UONI 13/55

Figure 2. Diagram of time between short circuits for coated electrodes



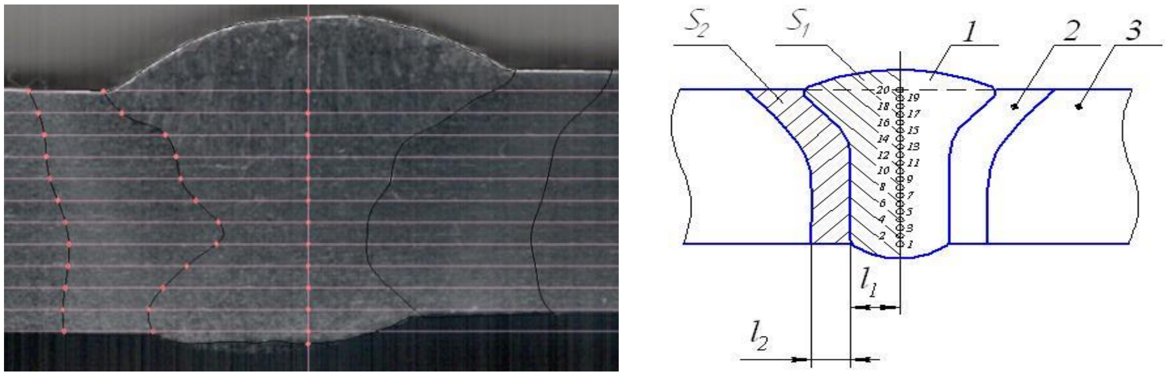
LB-52U UONI 13/55

Figure 3. Diagrams of short circuits time for coated electrode

The diagrams analysis (Figures 2 and 3) shows a greater stability of the electrode metal transfer to the welding pool when welding with an inverter power source. It means that the drop transfer time shortens and the number of short circuits increases, i.e. a finer drops of electrode metal drop are transferred [8, 9] which can be explained by a high short-circuit current increase rate with the inverter rectifier in contrast to the diode (three-phase) one in which the current increases slower and in a random way.

Reducing the arc burning time when welding with an inverter power source changes the heat input to the welded product which aligns with the results of [10, 11]. We have made a series of welds using different types of equipment: inverter, diode and single-phase rectifiers. A pipe of low-alloyed steel containing 0.09% C, less than 2% Mn, less than 1% Si with dimensions 159 × 6 mm was welded (S17 joint) with the following electrodes: bottom run – LB-52U (d = 2.6 mm), welding current I = 50...60 A; filling – LB-52U (d = 3.2 mm), welding current I = 80...90 A.

The results of macrosection treatment (Fig. 4, a) using the procedure described in [12, 13] implemented as shown in Fig. 4, b, show that when using the inverter rectifier, the heat affected zone area decreases by 18% and its width is reduced by 25% in comparison with the diode rectifier.



a b

Figure 4. Macrosection processing scheme obtained by Compass 3D software:
a – steel sample; b – measuring scheme (point spacing is 0.5 mm):
1 – welded seam; 2 – HAZ; 3 – base metal; l_1 – distance from the weld axis to the weld-fusion line;
l_2 – HAZ width; S_1 – welded seam area; S_2 – HAZ area

Table 2. Experimental data of macrosections processing

Steel brand	Welded joint type according to the State Standard	Rectifier type	S_1, mm^2	l_1, mm	S_2, mm^2	l_2, mm
45	C17 thickness10 mm	Diode	133±5.1	4.06±0.04	95.5±2.9	5.17±0.04
		Invertor	129±2.6	4±0.04	80.6±2.8	3.34±0.03
		Single-phase	132±3.1	4±0.04	84±2.8	4.1±0.03
09G2S	C17 thickness 6 mm	Diode	23.6±0.4	3.33±2.6	51.8±0.53	2.08±0.06
		Inventor	21.4±0.3	2.89±0.94	42.6±0.28	1.58±0.04
		Single-phase	22.1±0.3	2.93±1.1	44.7±0.3	1.7±0.05

Analysis of the data in Table 2 shows that the HAZ area decreased by 15% and the average HAZ width lowered by 36% when using an inverter rectifier in comparison with the diode one. As proved in [14-17], destruction of welded structures most often occurs within HAZ, its structure, area and properties depending on the thermal cycle conditions. Thus the decrease in the HAZ area increases operational strength of the welded joint.

Conclusion

It is proved that the use of an inverter rectifier in comparison with a conventional diode one reduces an average time of arc burning at the periods of electrode melting and electrode metal drops generation by 36% on average, which helps to reduce overheating of the welded product. It also cuts down the HAZ area by 15% and the HAZ width by 36%, which contributes to improving welded joint performance.

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