IOP Conf. Series: Materials Science and Engineering **681** (2019) 012037 doi:10.1088/1757-899X/681/1/012037

Assessment of welding working properties of power supplies

Yu N Saraev [1], D P Ilyashchenko[2], M A Krampit[2], V M Semenchuk[1], A S Nepomnyashchiy[1]

[1] Institute of Strength Physics and Materials Science SB RAS, Tomsk
[2]National research Tomsk Polytechnic University, Tomsk;

E-mail: mita8@rambler.ru

Abstract. The welding working properties of power supplies are the basic indicators of efficiency of their application when forming permnanent joints of critical duty constructions. Growth of the share of welded structures made of difficult-to-weld steels and alloys requires more advanced welding equipment characterized by better static and dynamic characteristics and ensuring optimal thermal welding cycles. In the paper the authors present their own view of the necessity of power supplies welding working properties assessment from the perspective of quantitative assessment of welding conditions indicators. It allows most complete characterizing of the process flow parameters.

1. Introduction

Today fusion welding is one of the key technologies in all industries. Meanwhile the quality factors of the weld joints and deposited surfaces depend not only on the technological capacity of the mechanical equipment but also on the versatility of the process implemented. The versatility of the process means the ability to keep the electrical and thermal characteristics unchanged or changing periodically according to a specified program at the level of instantaneous values [1]. Solution of the given problem is becoming more and more relevant as the technological development sets ever increasing requirements to the quality of the welding constructions and efficiency of the welding production.

In Russia the share of welded structures made of difficult-to-weld steels and alloys grows every year. Welding this type of steels and alloys requires equipment ensuring optimal thermal cycles [2] which demands application of new generation power supplies with improved static and dynamic performance [3]. The given characteristics determine the welding working properties of power systems and their quantitative assessment provides complete characteristics of the quality factors of the technical process. Up to now the welding working properties of power supplies have been registered in strict accordance with State Standard 25616-83 and State Standard 9466-75. The given standards allow getting a quality assessment by counting the number of points – good, satisfactory, bad. This way one cannot get objective information about the advantages of this or that power supply or applied welding materials.

Goal of research: Estimating the relationships between the quantitative indicators of the welding working properties of power supplies for manual metal-arc welding and the process performance specified by current standards in their assessment.

2. Experimental method and procedure.

To eliminate the shortcoming described above we developed a method of quantitative assessment of the welding working properties [4]. We chose the following power supplies as the basic ones: power supply made in accordance to the classic circuit of welding rectifier – VD-306E type (diode rectifier) and inverter power supplies: “ARC 250” (WS Weldeship) (inverter 1); “Resanta: SAI 250 PROF” (inverter 2); “Fubag INTIG 200 SYN PLUS” (inverter 3). The power supplies listed above have different static and dynamic performance determined according to the external characteristics presented in Figure 1. The dynamic properties of the power supplies can be estimated by analyzing the oscillograph charts of current and arc voltage presented in Figure 2.

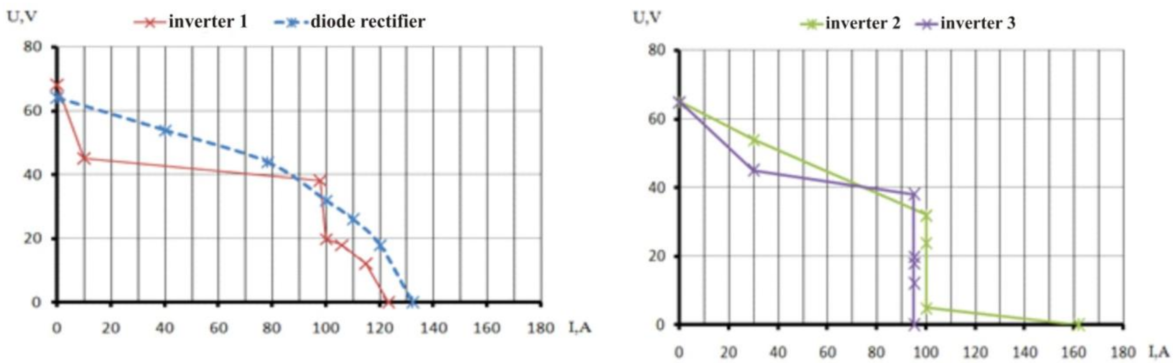


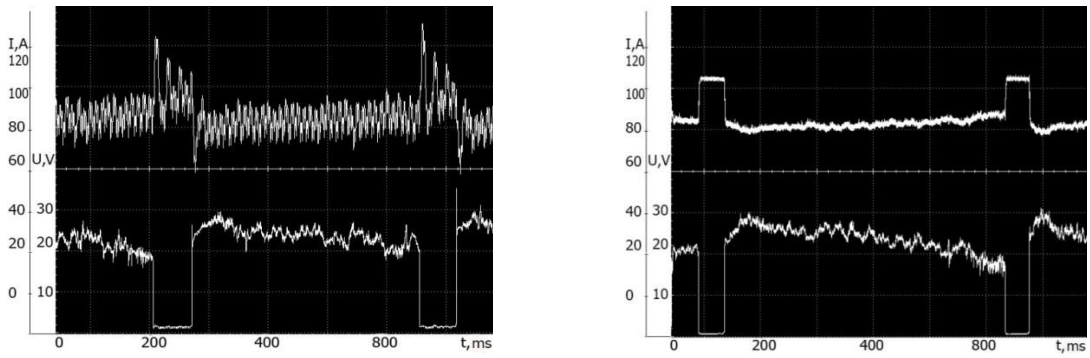
Figure 1. External characteristics of power supplies.

According to the method mentioned above we studied how the alteration rate of the basic energy parameters within the separate welding microcycles completed with power supply from the sources with the different types of energy conversion upon affects the stability of the surfacing process according to the conditions described in Table 1.

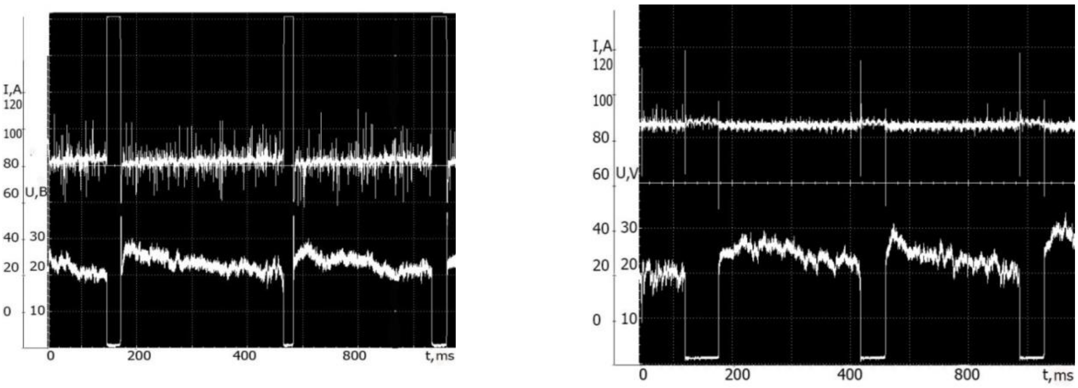
Table 1. Parameters of experimental surfacing

Power supply	Electrodes	Mean values of parameters recorded with oscillograph AKIP-4122/10.
Diode rectifier	OZCh-4	I_{arc}= (84.4 ± 2.7) A; U_{arc}= (21.9 ± 0.6) B; V_{ws}= 0.25 m/min
Inverter 1		I_{arc}= (84.5 ± 2.7) A; U_{arc}= (22.5 ± 0.7) B; V_{ws}= 0.25 m/min
Inverter 2		I_{arc}= (87.5 ± 3.1) A; U_{arc}= (21.3 ± 0.5) B; V_{ws}= 0.25 m/min
Inverter 3		I_{arc}= (85.6 ± 2.4) A; U_{arc}= (21.2 ± 0.4) B; V_{ws}= 0.25 m/min.

Here, I_{arc} – mean value of arc current; U_{arc} – mean value of arc voltage; V_{ws} – estimated value of welding speed.



a b



c d

Figure 2. Oscillograph charts of the current in the welding circuit and voltages between the electrode and the workpiece (electrodes OZCh-4, 3 mm in diameter): a – diode rectifier; b – inverter 1; c – inverter 2; d – inverter 3.

3. Discussion of obtained results.

Initial arc striking (the first property of the welding working parameters according to State Standard 25616-83) does not cause any problems to inverter power supplies as they all have HOT START function while the diode rectifier does not.

The term "Arc stability" is the second property according to State Standard 25616-83. Its physical meaning was most completely formulated by Yu. N. Lankin in his paper [5]: "The process of welding with parameter deviation from mean values not exceeding the specified level is called stable. The material measure of stability is parameter deviation from its mean value. Parameter deviation from its mean value is understood as its dispersion, standard deviation or coefficient of variability". Analysis of obtained results (Table 1) shows growth of short circuits of the arc space under the identical values of the surfacing conditions parameters indicating the advantages of inverter rectifiers over the diode ones.

Table 2. Results of statistical analysis of current and voltage oscillograph charts recorded when completing the technical studies

Type of power supply	Parameter				
	τ_{sc}, ms ± $\sigma_{\tau sc}$, ms	T_{st}, ms ± σ_{Tst}, ms	I_{min}, A	$I_{k.z.}$, A	$\frac{I_{arc}}{I_{k.z.}} \to 1$
Diode rectifier	61.3±9.4	750±295	58.28±1.8	127±6.5	0.66
Inverter 1	45.9±9.7	658.1±118.8	76.9±1.5	105±3	0.8
Inverter 2	22.6±2.7	295.5±45.5	14.1±0.8	162±1.4	0.54
Inverter 3	37.1±11.8	310.2±34.9	83±1.1	88.1±0.9	0.97

Here τ_{sc} is the short circuit duration of the arc space; ± $\sigma_{\tau sc}$ – the standard deviation of short circuit duration; $T_{st} = (\tau_{sc} + \tau_{ad})$ – cycle time; τ_{ad} is arc duration; σ_{Tst} – standard deviation of cycle time; I_{arc} – mean value of arc burning current; I_{sc} - mean value of short circuit current.

We analyzed the obtained oscillograph charts for the current in the welding circuit and for the voltage between the electrode and the work piece (Figure 1, Table 2) when applying power supplies with different type of energy conversion with consideration to:

- parameters of electrode metal drop transfer from the electrode surface: the longest time of bridging is ensured by diode rectifier ($\tau_{к.з}$=61.3±9.4 msec) and the shortest – by inverter 2 ($\tau_{к.з}$=22.6±2.7 msec). Reduction of drop transfer time and increase of short circuits number when applying inverters proves that electrode metal is transferred by smaller electrode metal drops [6,7].

- maximal and minimal values of the welding current: the smallest value is ensured by inverter 3 (5 A) and the largest – by inverter 2 (148 A). High peak values increase the rate of the power supply response to the natural disturbing influences of the short circuits of the arc space, which improves the stability of the welding process.

With consideration to the facts mentioned above we can conclude that inverter power supplied ensure more stable process of arc burning as compared to a diode rectifier [8-11].

As for electrode metal spatter (third property according to State Standard 25616-83) we can confirm that it fully corresponds to the previously observed effect [12-14] and is connected to the welding process stability characteristics to a full extent. The more unstable the processes of arc burning and electrode metal transfer to the weld pool are the larger is spatter. To eliminate this negative effect inverter power supplies 1 and 3 use systems for limiting the explosion energy of the jumper between the electrode metal drop and the weld pool at the last moment of its life. Relation $I_{arc}/I_{K.Z.}\rightarrow 1$, on this interval, is going to one which allows efficient reduction of electrode metal spattering.

4. Conclusion.

Objective assessment of arc stability, quality of electrode metal transfer and weld formation as basic indicators of welding working properties of power supplies ensuring high frequency energy conversion requires reconsidering the assessment criteria for these parameters according to State Standard 25616-83 as well as the assessment criteria for these parameters according to State Standard 25616-83 as they do not allow objective judgment about the advantages and disadvantages of the power supplies used. Further application of current standards makes it impossible to forecast the operational characteristics of the weld joints due to the unpredictability of the working welding properties of power supplies ensuring high frequency energy conversion and, as a result, it makes impossible obtaining the required properties of permanent joints in critical duty constructions [15,16].

Acknowledgments

The paper is completed under the agreement on scientific and technological cooperation between the National research Tomsk Polytechnic University and Institute of Strength Physics and Material Science SB RAS as well as the programs of fundamental scientific research of state academies of sciences for 2018-2019, project III.23.2.1.

References

[1] Exploratory studies to increase the reliability of critical metal structures operating under extreme loads and low climatic temperatures / Chapter 5 in the book: High technology in the projects of the RSF. Siberia / Ed. by S.G. Psahye and Yu.P. Sharkeev. – Tromsk: NTL publishers, 2017. – 428 p. ISBN 978-5-89503-607-5. P. 134-202.

[2] Efimenko L.A., Ramus A.A., Merkulova A.O. Features of the decomposition of austenite in the heat-affected zone during welding of high-strength steels // Physics of metals and metal science. – 2015, vol. 116. – p. 520 – 529.

[3] Loos A.V. Lukutin A.V., Saraev Yu.N. Power supplies for pulsed electrical processes. - Publishing Printing Company of TPU. – Tomsk. – 1998. – 159 p.

[4] Saraev, Y.N., Chinakhov, D.A., Ilyashchenko, D.I., Kiselev, A.S., Gordynets, A.S. Investigation of the stability of melting and electrode metal transfer in consumable electrode arc welding using power sources with different dynamic characteristics (2017) Welding International, 31 (10), pp. 784-790.

[5] Lankin, Yu.N. Stability indices of the process of arc welding with a consumable electrode / Yu.N. Lankin // Automatic welding. – 2011. – № 1. – P. 7–15.

[6] Mazel A.G. Technological properties of the electric arc. "Mashinostroyeniye", 1969, 178 p.

[7] Erokhin A.A. Basics of fusion welding. Physico - chemical laws. "Mashinostroyeniye". 1973, - 448p.

[8] Saraev Yu.N., Sleptsov O.I, Bezborodov V.P., Nikonova I.V., Tyutev A.V. Fatigue fracture analysis, structure and properties of welded joints used in Siberia and the Far North //

Installation and special works in construction. – 2005. - № 8. – p. 18 - 22.
[9] Saraev Yu.N. Experience in the development and practical application of adaptive pulsed-arc welding methods for the construction and repair of trunk pipelines // Problems of Materials Science. – 2015. – № 1 (81). – p. 210 - 218.
[10] Evaluation of the welding properties of equipment with inverter power supplies according to energy characteristics Gladkov E.A, Yushin A.A, Perkovsky R.A., Mymrikov S.A., Brodyagin V.N. Welding and diagnostics. 2011. № 1. P. 31-35.
[11] Development of criteria for an operational assessment of the welding properties of modern welding equipment Yushin A.A., Gladkov E.A. Welding and diagnostics. 2010. № 4. P. 52-54.
[12] Fedko V.T. Theory, technology and means of reducing spatter and labor intensity when welding in carbon dioxide. Tomsk: Tomsk State University, 1998. – 432 p.
[13] Fed'ko, V.T., Zernin, E.A. Main spattering reasons and protection methods of parts to be welded from welded metal spatters at CO2-welding (2005) *Svarochnoe Proizvodstvo*, (1), pp.37-3
[14] Il'yashchenko, D.P., Zernin, E.A. Determination of metal losses through splashing using different power sources (2011) *Welding International*, 25 (1), pp. 69-72.
[15] Saraev Yu.N., Bezborodov V.P., Grigoryeva A.A., Lebedev V.A., Maksimov S.Yu., Golikov N.I. Management of the structure and properties of welded joints of critical systems of engineering for adaptive pulsed-arc welding methods // Problems of Materials Science. – 2015. - № 1 (81). – p. 127 -132.
[16] Saraev Yu.N., Shpigunova O.I. A mathematical model of melting and transfer of electrode metal with systematic short circuits of the arc gap // Welding production. – 1992. - № 6. – p. 28 - 31.