

Improving Hygienic Characteristics of Coated Electrodes for Welding High-Alloy Steels

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Abstract: The article presents the results of experimental studies showing that the use of an inverter power supply instead of a diode rectifier provides: fine-droplet electrode metal transfer which reduces generation time by 46% and transfer time by 28%; transfer of alloying elements from welding materials into the weld metal which reduces its loss from the welding line by 6% and the heat affected area by 3%; reducing the emission rate of welding fumes and their components by 23%; reducing specific emission of welding fumes and their components by 23%.

1. Introduction

In 2013 the American Conference of Governmental Industrial Hygienists (ACGIH) revised its recommendations on the quantitative composition of welding fumes and proposed to reduce the maximum permissible concentration (MPC). It is obvious that the above changes will become a regulatory standard that will make manufacturers of welding consumables to seek ways of adapting to the new conditions. In many countries and especially in the US, judicial proceedings between welders who suffer from occupational diseases and producers of welding materials take place. Thus, measures aimed at reducing the negative impact of welding fumes on human health are necessary. The above facts show that work at improvement of sanitary and hygienic characteristics of welding is going on at the international level [1].

An analysis of research works [2-4] showed that the quantitative and qualitative composition of welding fumes has a negative impact on human body, especially when welding high-alloy steels.

Arc welding of high-alloy chromium-nickel steels causes air pollution in the working area with welding fumes which contain harmful substances of various hazard categories (State Standard 12.1.005-88): I - hexavalent chromium, and nickel; II - manganese and soluble fluoride; III - trivalent chromium and insoluble fluorides.

Minimizing welding fumes and the most toxic components in their composition is an urgent problem that must be solved.

This paper deals with a hygienic assessment of coated electrodes of CL 11 type intended for welding high-alloy steels and finding ways to reduce the toxicity of welding fumes.

One of the ways to solve this problem is to use power supplies implementing various forms of energy conversion [5-7], which have an impact on the physical and chemical processes in welding.



Work [8] describes MMA model and proves that the amount of welding fumes in the air of the working area is reduced if the amount of alloying elements transiting into the weld and the slag crust is increased. Efficiency of transition of alloying elements from the electrode to the weld can be improved by reducing heat input into an electrode metal drop and minimizing size of droplets in droplet transfer.

2 Methods and techniques of experimental research:

Assessment of the stability of the welding process was performed using the statistical analysis of welding current and voltage oscillograms generated by power supplies having different dynamic characteristics. The main power supplies have been chosen: a power supply made as a common welding rectifier, and the power inverter. The study of dynamic characteristics was based on a comparison of current and voltage oscillograms obtained using the following devices: digital storage oscilloscope "AKIP-4122 / 1V"; Differential Probe "Pintek Electronics DP-50"; "current probe PR 1030" puller; OWON_Oscilloscope_2.0.8.26 software. The results of the study are presented in Tables 1, 2 and in Figure 1.

Table 1 - Welding modes with CL11 electrodes from various energy supplies

| Power supply | Electrode type | Average values of a welding mode parameters | Number of short circuits |
|-----------------|----------------|---|--------------------------|
| Diode rectifier | CL11 | Current 86 A Voltage 24.5B Welding speed 0.27 m/min | 12 |
| Inverter | | | 24 |

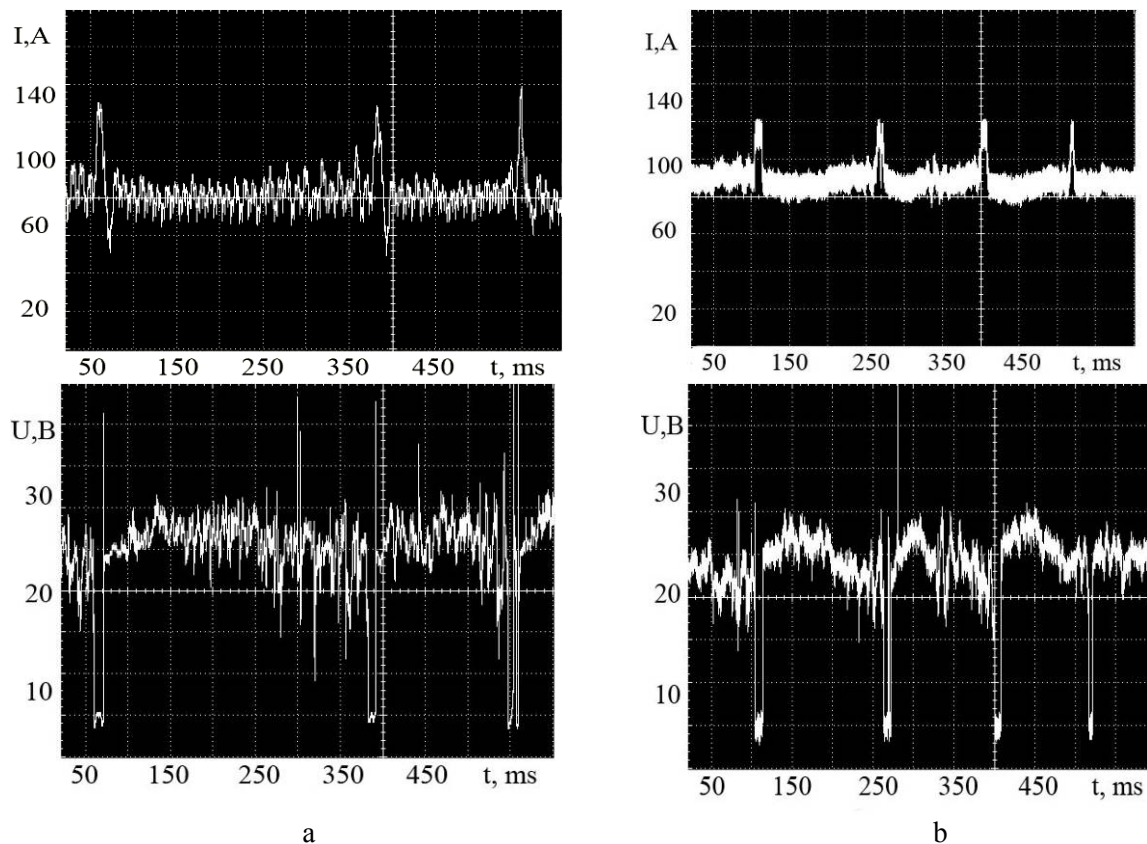


Figure 1. Oscillograms of voltage and current of drop transfer cycle (Type CL 11 electrodes with a diameter of 3 mm): a) - diode rectifier; b) - inverter

3. Results

Analysis of the oscillograms shown in Figure 1 (Table 1.2) shows that when a power supply based on high frequency energy conversion (an inverter) is used, the droplet transition time decreases and the quantity of short circuits increases. In this case the droplets in electrode metal transfer are smaller in size which is proved to changes the chemical composition of the weld metal [9, 10]. To confirm this supposition microradiography of chemical composition at areas 1, 2, 3 shown in Fig. 3 and Table 3 was carried out (Fig. 2).

When MMA deoxidation - alloying of the weld metal occurs combined - through electrode coating.

Table 2 - Static analysis of dropt transfer parameters of CL11 coated electrodes metal

| Parameters | Power supply | |
|---|----------------|----------|
| | Diod rectifier | Inverter |
| The duration of short-circuit arc gap, m/s | 12 | 8.7 |
| The standard deviation of short-circuit time, m/s | 3.76 | 3.52 |
| The coefficient of time variation, % | 31.3 | 28.9 |
| Time of short-circuit cycle, m/s | 249 | 140 |
| The standard deviation of short-circuit cycle time σ , m/s | 76.3 | 45.8 |
| Variation coefficient of short-circuit time, % | 30.6 | 32.7 |

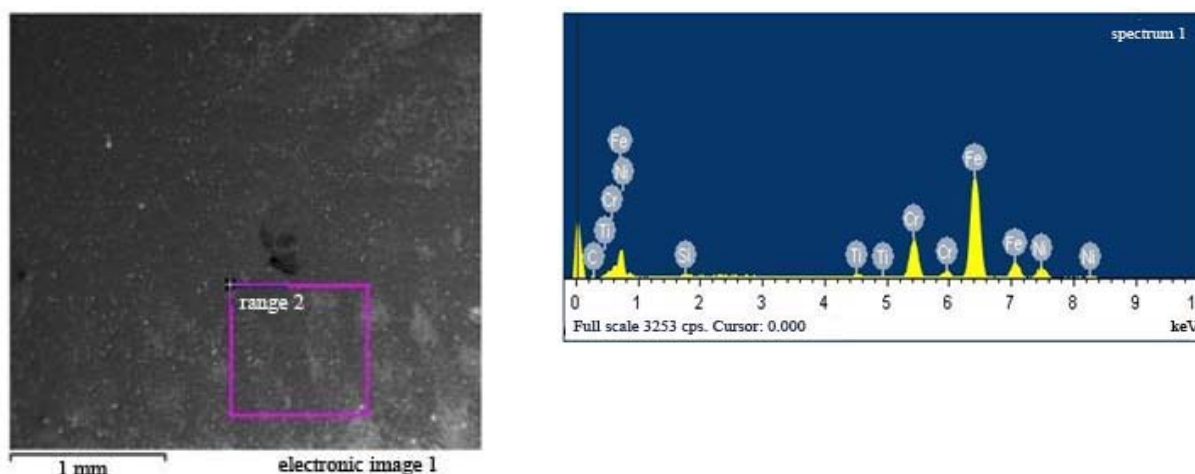


Figure 2. Electron microprobe analysis obtained by INCA consoles (Oxford Instruments)

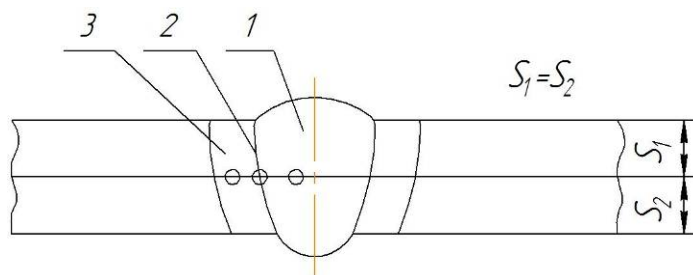


Figure 3. The scheme of electron microradiography: 1 – Weld; 2 – Weld line; 3 – HAZ

Table 3 - Chemical composition of weld metal made of steel H18N10T obtained electrodes brand CL 11

| Elements content | Power Supply | | | |
|------------------|-----------------|-------|----------|-------|
| | Diode Rectifier | | Invertor | |
| | Weight % | Atom% | Weight % | Atom% |
| Weld (1) | | | | |
| Si K | 0.36 | 0.71 | 0.38 | 0.75 |
| Ti K | 1.44 | 1.45 | 1.90 | 1.91 |
| Cr K | 18.54 | 19.66 | 19.21 | 20.37 |
| Fe K | 67.71 | 66.85 | 69.45 | 68.57 |
| Ni K | 10.19 | 9.57 | 10.81 | 10.15 |
| Weld line (2) | | | | |
| Si K | 0.50 | 0.98 | 0.56 | 1.10 |
| Ti K | 0.60 | 0.69 | 0.65 | 0.75 |
| Cr K | 16.45 | 17.45 | 17.40 | 18.42 |
| Fe K | 70.52 | 69.53 | 71.44 | 70.77 |
| Ni K | 10.87 | 10.11 | 11.01 | 10.20 |
| HAZ (3) | | | | |
| Si K | 0.50 | 0.97 | 0.53 | 1.05 |
| Ti K | 0.61 | 0.70 | 0.76 | 0.88 |
| Cr K | 17.19 | 18.21 | 17.41 | 18.45 |
| Fe K | 70.96 | 70.00 | 70.70 | 69.73 |
| Ni K | 10.63 | 9.98 | 10.71 | 10.05 |

An analysis of data in Table 3 shows an increase of the alloying elements in all the weld areas investigated when an inverter is used, which can be explained by fine-droplet electrode metal transfer (Table 2).

Samples of welding fumes for hygienic assessment of the electrodes were collected in the course of welding beads on plates of H18N10T steel with the electrode being tested. A diode rectifier and an inverter were used as the power supply. Bead welding was carried out with direct reverse polarity current at optimal conditions. Welding fumes were captured by means of a special cover insulating the weld zone.

At the same time, according to instructions [11, 12], welding fumes deposited on the filters of FPP-15-1.5 tissue when assessing the level of emission and on AFA-HA-18 filters when for subsequent chemical analysis of welding fumes samples. The weight of the emitted welding fumes and their components was determined by the gravimetric method. For this purpose, at least five welding fume samples were selected. The research results (Table 4, 5, 6) were subjected to statistical analysis [13].

Table 4 - The emission rate of welding fumes and their components (g/min)

| Electrode type (diameter, mm) | Power supply type | CA | CrO ₃ | Cr ₂ O ₃ | Mn | Ni | F soluble | F insoluble |
|----------------------------------|-------------------|-------|------------------|--------------------------------|-------|--------|-----------|-------------|
| CL-11 (3) | Diode rectifier | 0.257 | 0.012 | 0.006 | 0.007 | 0.006 | 0.012 | 0.013 |
| | Inverter | 0.2 | 0.09 | 0.004 | 0.005 | 0.0045 | 0.01 | 0.01 |

Table 5 - Specific emission (g/kg) of welding fumes and their components

| Electrode type (diameter, mm) | Power supply type | CA | CrO ₃ | Cr ₂ O ₃ | Mn | Ni | F soluble | F insoluble |
|----------------------------------|-------------------|-------|------------------|--------------------------------|------|------|-----------|-------------|
| CL-11 | Diode rectifier | 10.48 | 0.48 | 0.26 | 0.31 | 0.26 | 0.50 | 0.51 |
| | Inverter | 8.07 | 0.37 | 0.20 | 0.24 | 0.20 | 0.42 | 0.42 |

Table 6 - Toxic level of TLVf welding fumes and NHL air exchange

| Electrode type (diameter, mm) | Power supply type | TLV _f , mg/g ³ | NHL, m ³ /h |
|----------------------------------|-------------------|--------------------------------------|------------------------|
| CL-11 | Diode rectifier | 0.15 | 1480 |
| | Inverter | 0.1 | 1000 |

According to the research results (Table 4, 5, 6) it has been found that the use of inverter rectifiers improves working conditions of welders in manual arc welding as compared with diode rectifiers. It reduces: a quantitative component of welding fumes from 0.257 to 0.2 (19%), manganese from 0.007 to 0.005 (23%), chromium oxide from 0.012 to 0.09 (24%).

Conclusion

The research has shown that the use of an inverter power supply instead of a diode rectifier provides:

- 1) fine-droplet electrode metal transfer which reduces generation time by 46% and transfer time by 28%;
- 2) transfer of alloying elements from welding materials into the weld metal which reduces its loss from the welding line by 6% and the heat affected area by 3%;
- 3) reducing the emission rate of welding fumes and their components by 23%;
- 4) reducing specific emission of welding fumes and their components by 23%.

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