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Effect Of Dynamic Characteristics of Power Supplies on Aerosol Composition While Welding With Coated Electrodes

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Abstract. In the context of a significant increase in production output and use of welding technologies in the manufacturing of engineering products the problem of hygienic characteristics of working conditions in arc fusion welding is becoming increasingly important. The work represents how the dynamic characteristics of a power supply affect the transfer of alloying elements from a coated electrode into a base metal, a slag phase and a solid component of welding fumes.
Short-circuit current limiting in inverters reduces overheating of electrode metal drops by 15%; welding fumes quantitative component - to 38%; manganese - to 30%; thermal radiation intensity - by 37%.

1. Introduction

While manual metal arc welding (MMA), smoke pollution of the working area atmosphere, intense optical radiation and electrode metal sprinkling cause the greatest harm to the health of workers [1]. In the arc welding course reacting of the molten metal with slag and gas occurs, thereby forming welding fumes, consisting of solid particles and gas phase. The impact of welding fumes on the organism causes occupational diseases of welders. [1,2] examine how composition of welding fumes affect the following factors: electrode coating composition; welding conditions (current and voltage); current type and polarity; composition of a base metal and an electrode; electrode coating thickness; electrode diameter.

Optical radiation is the result of high-powered heat source combustion and includes infrared and ultraviolet radiation. In the same environment the optical radiation radiates in a direct line; when interacting with the environment it can be absorbed, reflected, refracted, undergo diffraction, interference and polarization [3,4].

A problem of electrode metal scattering now takes on new significance in connection with the large-scale implementation of air purification facilities in welding areas [5]. Air-intake systems are arranged at 0.25-0.40 m distance from the welding arc to work effectively. Almost all the small drops of up to 1 mm and larger, emitted toward air scoop, can be trapped into the system of dust extraction and purification. This significantly increases the mass loading on the filter, exceeding a design smoke loading, and causes a permanent threat of filters melting or ignition.

The factors mentioned above have negative impact on the respiratory system, sight sensors, skin cover and immune system.

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In recent years, [6], inverters are actively engaged in the market of power supplies for MMA. Their advantages are reduction in weight-and-size and cost of power sources as well as a significant improvement of control and quality of manufacturing methods.

2. Methods and results

The purpose is to investigate hygienic characteristics of manual arc welding with coated electrodes with the aid of different types of power supply (inverter rectifier Nebula - 315, diode rectifier VD - 306). Tests have shown [7] that using the inverter power supply changes the arc thermal effect on the drop of the electrode metal. Computations, performed by analytical method [8], show that, when using the inverter power source, an average amount of energy is Q_d = 0,13x107J per drop of the electrode metal, and when using a diode rectifier - Q_d = 0,156x107J.

Calculation of overheat temperature of the drops, during their passage through the arc gap with short circuits, is determined by the formula [9.10]:

$$\Delta T_k = \frac{1}{c}\left(\frac{q_1}{a \cdot \tau_{k.z.}^2} - \frac{1}{K}\right). \tag{1}$$

where $\Delta T_к$ - overtemperature of the molten metal on the electrode over the melting point, k; c – average specific heat of the liquid metal, J/K (0,84); q_1 – thermal capacity of the arc at the electrode end, J/c; K – coefficient characterizing the mass of metal that can be melted with an energy unit, g/J ($1{,}5 \cdot 10^{-3}$); $\tau_{k.z.}$- time of a short circuit of the arc gap with a drop, ms: $\tau_{k.z.}$=6,37ms for the diode rectifier; $\tau_{k.z.}$ =5,37 ms for the inverter power source [9].

Overtemperature $\Delta T_к$ of electrode metal drops (average value exceeding the melting point) is $\Delta T_к$ = 410^o C while welding with the inverter power supply, and 480^o C with the diode power supply. Overheating of the electrode metal [1, 2, 11] leads to changes in metallurgical processes in the drop, and as a consequence, change of the welding fume chemical composition. Thus the type of power supply affects the hygienic characteristics of the air in the welding area.

To confirm this, we conducted a comprehensive laboratory testing. Two pipe samples (welded joint C17 according to GOST 5264-80) 159x6 from 09Г2С steel were welded with electrodes with use of the diode rectifier ВД-306 and the inverter power supply Nebula-315ю in the following manner: root - LB-52U (d = 2,6 mm), welding current I = 50-60 A, backfills - LB-52U (d = 3.2 mm), welding current I = 80 - 90 A.

While MMA, dust and gases gross emission was investigated in laboratory conditions (welding was performed on 09Г2С steel samples using different types of power sources and electrodes coated with LB-52U base coating). We determined the amount of dust, emitted while welding, and its chemical composition, a content of manganese dust, qualitative and quantitative composition of the dispersion medium of resulting welding fumes. Air sampling to determine the level of air pollution was taken in the welder's breathing zone (the distance from the arc was 55 cm). For the investigations the following equipment was used: an aspirator for air sampling, model 822; an aneroid БАММ -1; an aspiration psychrometer МВ-4М; an analyzer «ЭЛАН-СО-50».

Table 1 shows components of welding fumes emitted while MMA (exhaust ventilation is switched off) using inverter and diode power supplies

It is obvious that, when using the inverter welding power source, fumes and manganese concentration is lower, and therefore, risks of toxic poisoning and threats of respiratory diseases is reduced for workers in the welding area. The inverter power supply limits short-circuit current, Figure 1.2 ($I_{max\ diode\ rectifier}$ = 140A;. $I_{max\ inverter}$ = 123A) resulting in less burnout of alloying elements (Table 2) Si to 0.08% and Mn to 0.2%, as confirmed by the author in [13].

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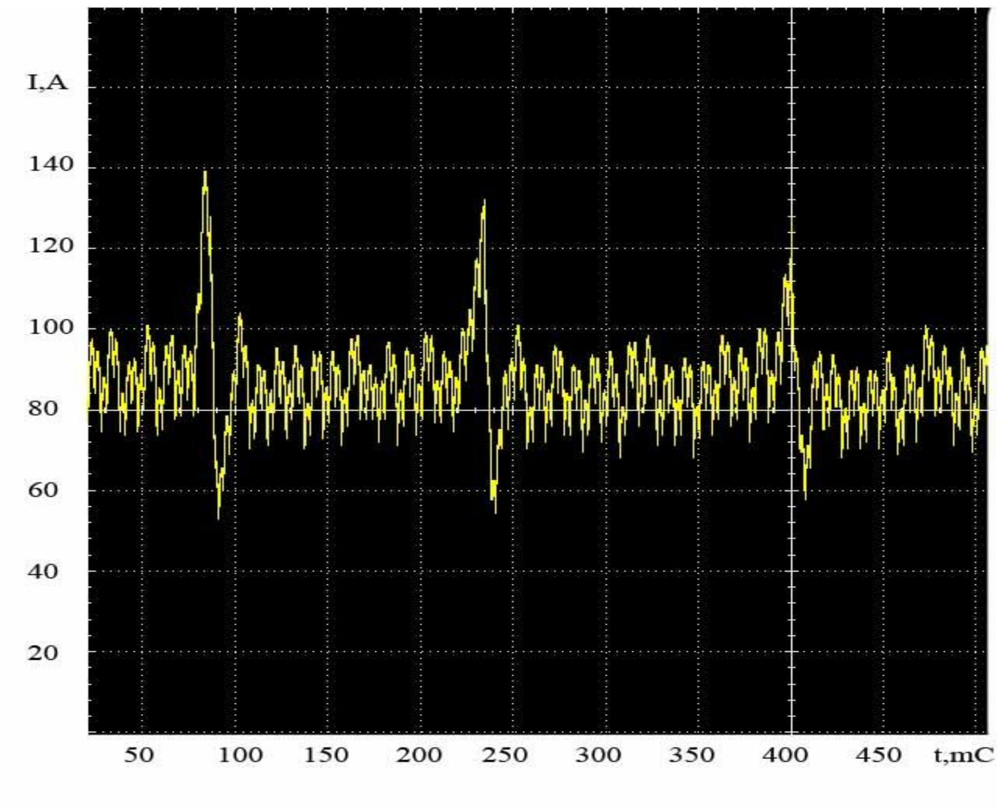
Table 1 - Emissions of dust. gases and other impurities while MMA using different types of power supply

Terms of sample selection	Name of element	Unit of measurement	Power supply		Maximum permissible concentration
			Inverter	Diod rectifier	
Materials LB - 52U Ø 3.2 mm. Steel 09Г2С	carbon monoxide	mg/m³	0.05	0.05	20.0
	nitrogen dioxide		below 0.6	below 0.6	2.0
	hydrogen fluoride		below 0.02	below 0.02	0.5
	Welding fumes		2.2±0.5	3.6±0.9	
	chromic anhydride		below 0.003	below 0.003	0.01
	chromium oxide		below 0.5	below 0.5	1.0
	Manganese		0.10±0.03	0.15±0.03	0.6



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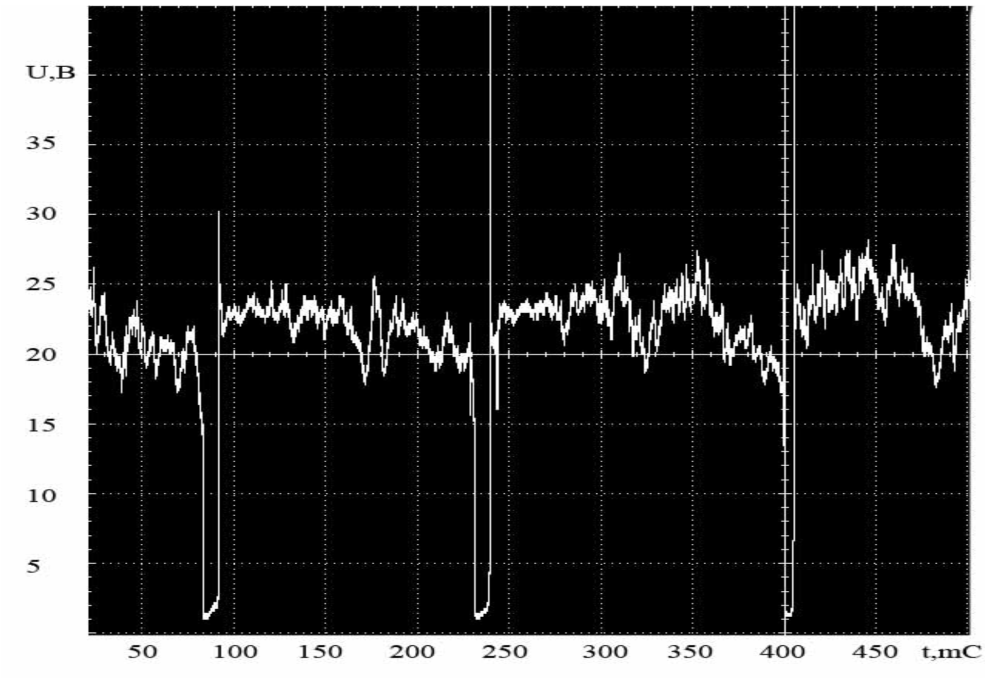
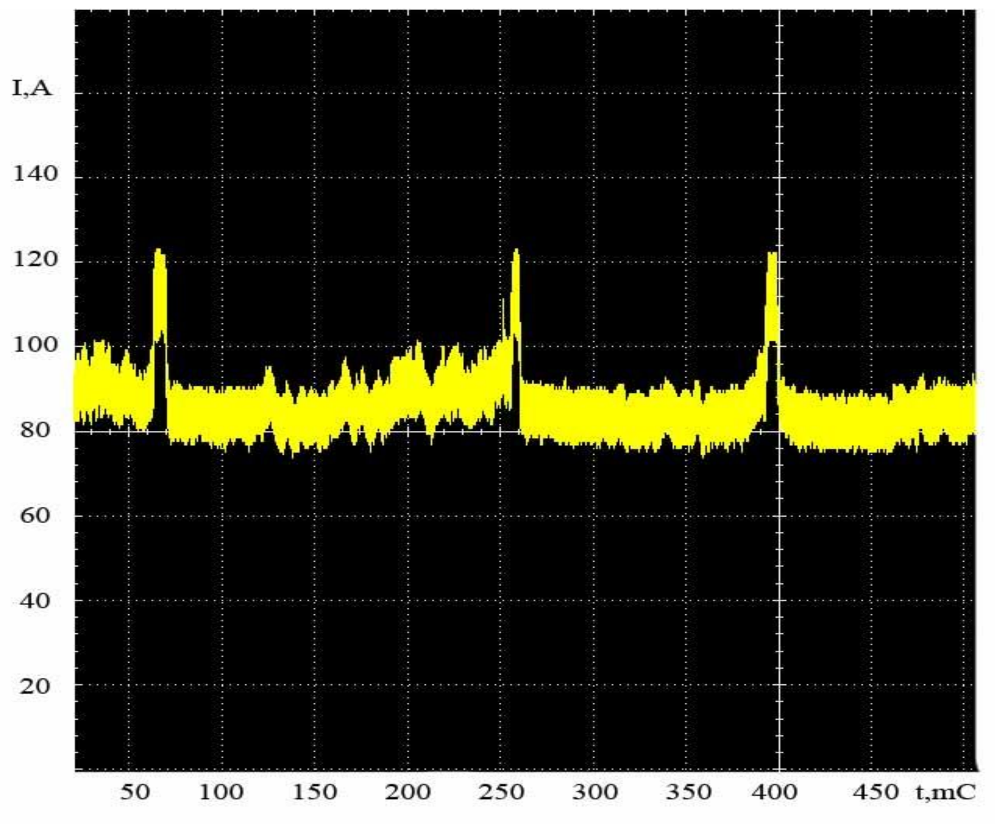


Figure 1 - Waveforms of voltage and current (electrodes LB-52U, 3,2 mm diameter) - diode rectifier



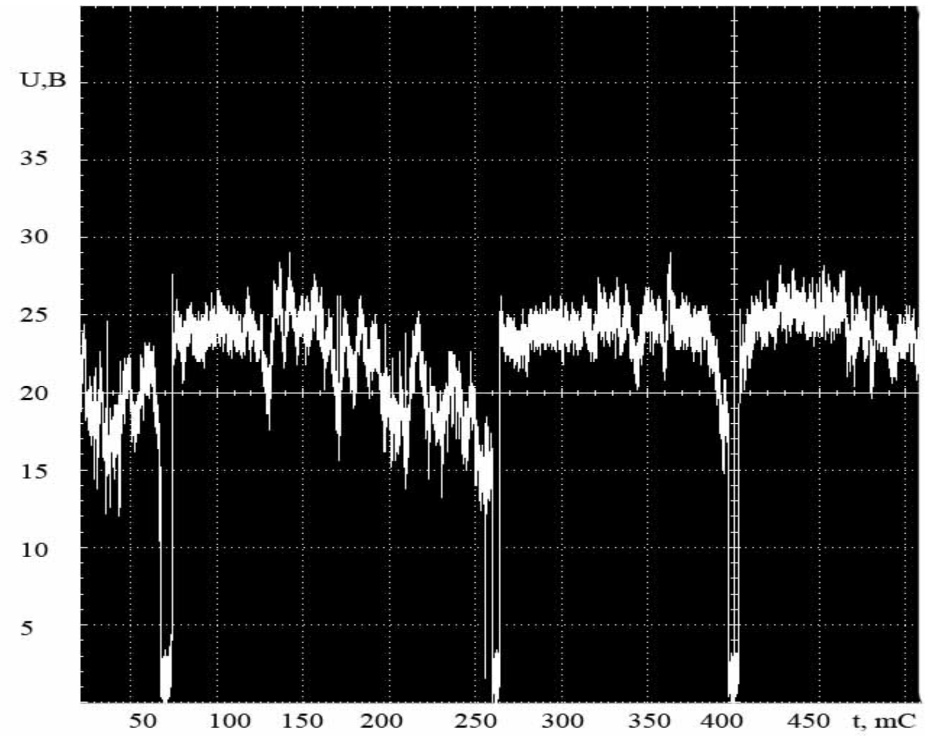


Figure 2 - Waveforms of voltage and current
(electrodes LB-52U, 3,2 mm) - inverter

Table 2 - Chemical composition of weld joints, pipe Ø159 × 6 (09Г2С steel), LB 52U electrodes

Power supply	Element content, mass %							
	C	Si	Mn	S	P	Cr	Ni	Cu
Diode rectifier	0.10± 0.012	0.52± 0.03	1.03± 0.05	0.010± 0.002	0.014± 0.003	0.03± 0.01	0.05± 0.01	0.03± 0.008
Inverter	0.09± 0.005	0.60± 0.03	1.23± 0.05	0.010± 0.002	0.014± 0.003	0.03± 0.01	0.06± 0.01	0.03± 0.008

Table 3 - Average chemical composition of slag

Electrodes	Power supply	CaO, %	SiO_2, %	TiO_2, %	NbO, %	MnO, %	Fe_2O_3, %	Cr_2O_3, %	Al_2O_3, %
LB-52U	Diode rectifier	38.66	25.37	9.57	0.10	7.21	13.89	0.17	3.61
	Inverter	36.27	24.187	8.74	0.05	7.48	18.31	0.15	3.66

Analysis of the readings (Tables 2 and 3) shows an increase in mass fraction of the alloying elements: Mn - 0,2%, Si - 0,08% in the weld metal, and a decrease in the proportion of oxides (SiO2, MnO) in the slag phase if using the inverter. This can be explained by the different heat content in molten metal drops while using inverter or diode power supply; that is confirmed by formula 1.

Heterogeneous equilibrium reactions occur between the slag ZnO, SiO_2 and the base metal, which depend on heat content of and temperature of drops (reactions are dissimilar when using different power supplies).

Effect of power supply's energy parameters, on irradiance while welding, was performed with use of radiometer "Кварц-41 – РАТ-2П " (Figure 3.).

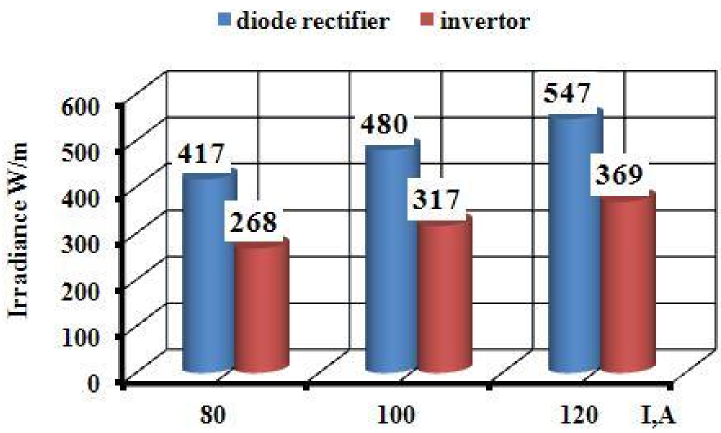


Figure 3 - Dependence of irradiance on welding current (electrodes LB 52U, dia. 3.2 mm)

Test results (Figure 3) show that a lower irradiance is observed when using an inverter power source; therefore, a level of light and heat exposure on workers in the welding area is diminished.

Electrode metal scattering depends on welding process stability. [14] proves a direct relation between scattering and a power of the short-circuit current; that is, if the power supply provides a ratio of $I_{sh.c.}/I_a \rightarrow 1$, it provides less scattering magnitude. Figures 1,2 show this ratio to be 1.38 for the inverter and 1.57 for the diode rectifier . This is also confirmed by earlier studies [7,15-18], resulted in relation between the type of a power supply and the amount of losses of electrode metal scattering. Histogram analysis (Figure 4) shows that Nebula-315 inverter power supply provides a significantly smaller amount of electrode metal scattering (0,3-3,4%), hence the use of coated electrodes is more efficient if compared with a diode rectifier VD-306 (4,4-5,71 %);

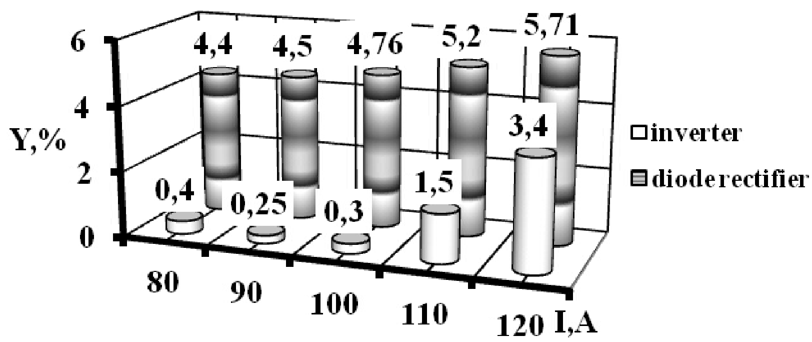


Fig. 4 - Effect of current on electrode metal scattering magnitude while MMA with LB -52U electrodes (base coat), 3.2 mm diameter.

3. Results and conclusion

In order to improve the environmental situation in the areas of welding works, it is recommended to use air trap filters equipped with metal drop pre-purification filters (mechanical dust precipitators - mostly "cyclones") or minimize scattering using inverter power supplies.

Investigations have established that use of inverter rectifiers improves hygienic conditions in welding areas while manual arc welding if compared with a diode rectifier, namely:
1) reducing of quantitative component of welding fumes to 38% and that of manganese to 30%;
2) diminishing of heat emission intensity by 37%.

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