

## **The effect of a pulsating spraying jet on the volume of air that comes in contact with metal electrodes during arc metallization**

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### **Abstract**

At electroarc spraying, there is intensive oxidation of the sprayed metal due to oxygen of the air, which leads to a significant decrease of the content of alloying elements in the coating and, accordingly, deteriorates the quality of the sprayed layer.

This issue was brought to light by the authors of scientific publications that proposed the use of kerosene, propane and air mixture, inert gases as a transportation gas, but these solutions led to a significant increase in the cost of the arc metalization process, and often had no quantitative calculations of the impact on the quality of coatings or were approximate.

The purpose of this paper is to provide a scientific justification for the concept of improving the quality of coatings by reducing the negative impact of oxygen of the air during arc metallization by using a pulsating spraying air jet.

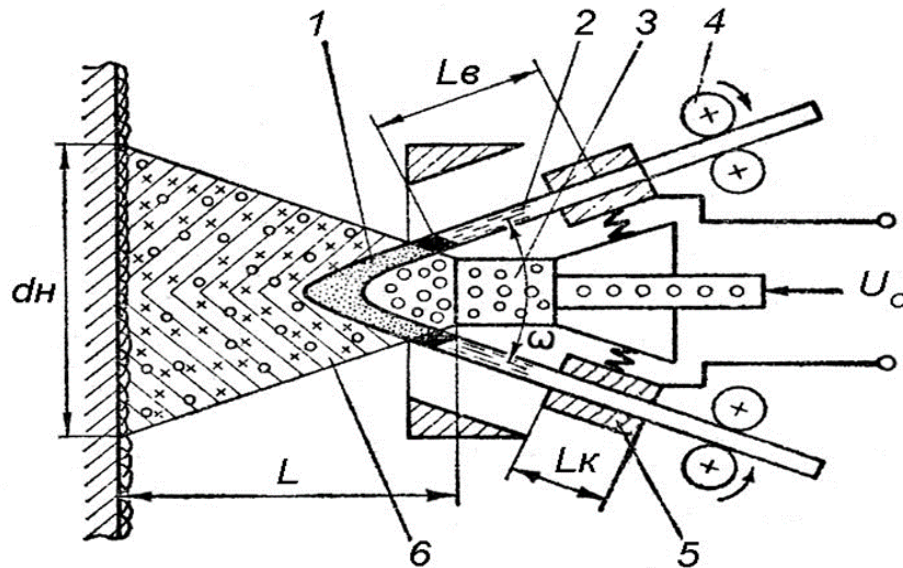
This paper presents a mathematical analysis of determining the amount of air at the formation of a controlled pulsating spraying airflow with specific pulses at arc metallization.

The results of the research have shown that the use of a pulsating air spraying flow at the application of coatings by arc metallization will reduce the burnout of alloying elements in the applied coating, which will improve the quality of the restored parts.

**Keywords:** alloying elements; oxygen; arc metallization; pulsating airflow; electrodes.

### **1.INTRODUCTION**

The process of arc metallization involves heating the ends of metal electrodes by an electric arc to the melting temperature and further spraying of liquid metal by a stream of compressed air [3,6,8]. The principal scheme of arc metallization is shown in Figure 1.



**Figure 1.** Circuit diagram of the electric arc metallization.

1 - arc burning zone; 2 - metal electrodes that are sprayed; 3 - nozzle; 4 - feed rollers; 5 - electric current supply; 6 - two-phase jet.

Determining components of the process of coating formation from the electrode metal particles that are melted is the heating of electrode ends to the melting temperature with further separation under the impact of a spraying jet.

## 2.MATERIALS AND METHOD

The authors suggested the pulsating influence of the spraying stream for separation and transportation of the material cut from the electrode ends during the arc metallization [7,10,12,14].

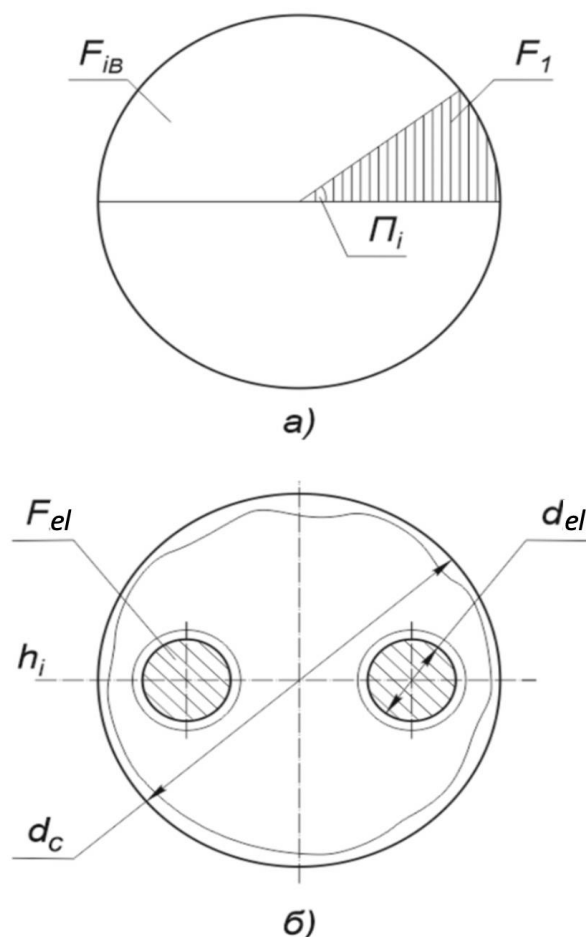
Determination of the real air flow rate, contacting with the metal of the spray electrodes, when using a pulsating spraying stream, is the main purpose of studies. Based on the scheme presented in Fig. 1, we determine the proportion of air from the total flow, which washes one electrode. The area of washing of one electrode will be equal to:

$$F_{bas m} = \pi d_{el} h_i, \tag{1}$$

where  $d_{el}$  - electrode diameter, mm

$F_{bas m}$  - area of washing of one electrode by the stream of air, m<sup>2</sup>;

$h_i$  - the nominal thickness of the spraying stream, contacting with the electrode metal, mm.



**Figure 2.** Calculation scheme of electrodes location in the spraying airflow (washing scheme)

a - channel opening area depending on the valve rotation; b - nozzle scheme.  
The area of washing for two electrodes will be equal to:

$$F_{ni} = 2\pi d_{el} h_i, \quad (2)$$

where  $h_i$  – nominal thickness of the spraying flow, in contact with metal electrodes, mm

$F_{ni}$  – a full area of washing of two electrodes by the spraying flow, mm<sup>2</sup>

An important indicator of the element burnout process is the amount of oxygen of the airflow that affects the molten metal of the electrodes. The total flow rate of air washing the electrodes is calculated by the formula:

$$G_{hi} = G \frac{F_{ni}}{F_c} = G \frac{8d_{el}h_i}{d_c^2}, \quad (3)$$

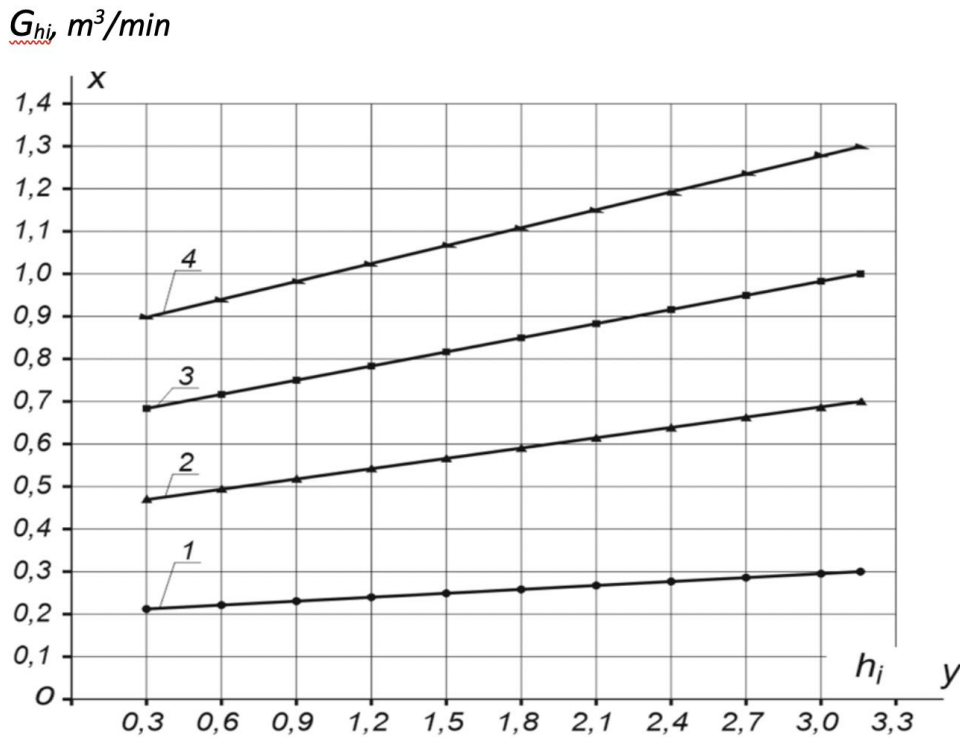
where  $G$  – the airflow rate at arc spraying, m<sup>3</sup> per s;

$F_c$  – cross-sectional area of the metallizer nozzle, m<sup>2</sup>;

$d_{el}$  – diameter of electrodes, which are sprayed, m;

$h_i$  – a volume of the layer of flow, which washes the electrodes, m.

A summary graph of the dependence of the airflow rate value, which washes the electrode of the total gas flow with an increase in the conventional layer is shown in Figure 3.



**Figure 3.** Nature of change of air flow rate in case of pulsator duct overlapping for assumed values

1 –  $h_i = 0,1$ ; 2 –  $h_i = 0,2$ ; 3 –  $h_i = 0,3$ ; 4 –  $h_i = 0,4$ .

Fig. 3 shows that the level of airflow rate in contact with liquid metal, has a linear character, increases with the growth of conditionally accepted thickness of the layer of spray air in the area of interaction with metal electrodes.

For the case of pulsating spraying, we determine the flow rate of air washing the electrodes at the overlap of the pulsator valve, which depends on the ratio of washing areas at the overlap and the area of the flow cross-section without

overlap,  $F_{hi}^P$ . We set the ratio of areas  $K = \frac{F_{hi}^P}{F_c^P}$ , substituting the values from equations (4.13) and (4.14), and obtain:

$$K = \frac{8\pi d_{el} h_i}{(\pi - \pi_i) d_c^2}, \tag{4}$$

where  $d_{el}$  – the diameter of the sprayed electrodes, m;

$h_i$  – the volume of the flow layer washing the electrodes, m;

$d_c$  – diameter of pulsator channel, mm.

Considering the ratio of the areas ( $K$ ) we determine the value of the airflow rate, which washes the electrodes, if there is an overlap of the nozzle channel

$$G_{ni} = G \frac{8\pi d_{el} h_i}{(\pi - \pi_i) d_c^2}, \quad (5)$$

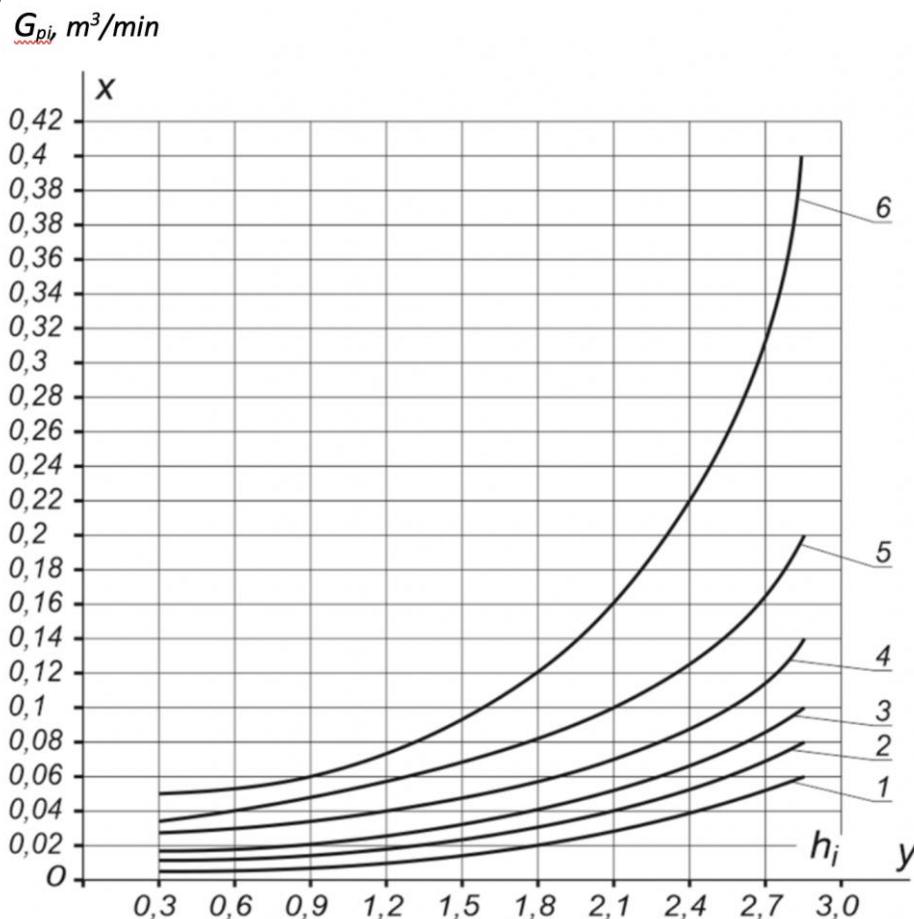
where  $G$  – airflow rate for a given diameter of the metallizer nozzle,  $m^3$

Expression (5) makes it possible to determine the flow rate of the spray air washing the metal electrodes in one pulsator revolution, depending on  $h_i$ . We determine the flow rate of the air washing the electrodes at different speeds of rotation of the pulsator valve  $G^f = \frac{G_{ni}}{n}$  or for the overlap frequencies  $n$ , and the result is:

$$G^f = G \frac{8\pi d_{el} h_i}{(\pi - \pi_i) d_c^2 n}, \quad (6)$$

where  $n$  – the rotational speed of the pulsator per second.

A summary graph of the influence of the pulsation frequency of the spraying jet of the metallizer on the volume of gas flow, which washes the metal electrodes is shown in Figure 4.



**Figure 4.** A summary graph of the influence of the pulsation frequency of the spraying jet of the metallizer on the consumption of the gas washing the metal electrodes

1 -  $n = 120$  Hz; 2 -  $n = 100$  Hz; 3 -  $n = 80$  Hz; 4 -  $n = 60$  Hz; 5 -  $n = 40$  Hz; 6 -  $n = 20$  Hz.

From Fig. 4. It is not difficult to see that as the pulsation frequency of the spraying flow increases and the contact area of the flow increases, the flow rate of the contact air increases.

For practical application of the previously presented calculations, an important condition is to determine the oxygen mass of the airflow, washing the electrodes, which corresponds to the spraying of a certain mass of electrodes.

Let's determine the oxygen mass of the airflow at a pulsating flow when spraying a certain amount of metal during the time  $T$ . We determine the  $T$  value from the calculation of spraying 10 cm electrodes at different feed rates.

$$T = \frac{l}{v_{el}}, \quad (7)$$

where  $l$  – the length of the electrode to be sprayed (10cm is accepted)

$v_{el}$  – feed speed of the electrode to be sprayed (6-10 cm/sec; 3.8-4.2 m/h).

Based on the conducted researches, from the data mentioned earlier, we determine the mass of oxygen ( $m_{o_2}$ ) at the spraying of the steel electrode Q345 (GB/T1591) with length  $l = 10$  cm, diameter  $d_{el} = 2.0$  mm, at electrode delivery speed  $v_{el} = 3.8$  m/min, (6,3 cm/sec), airflow rate  $2$  m<sup>3</sup>/min, according to [51] for the nozzle diameter 6 mm, air density  $\gamma_{O_2} = 1.3$  kg / m<sup>3</sup> and volume content of oxygen in the air stream  $a_{o_2} = 21\%$ );

The mass of oxygen of the pulsating spraying flow is determined from equation (6), considering expression (7) at electrodes spraying, and is presented in the form:

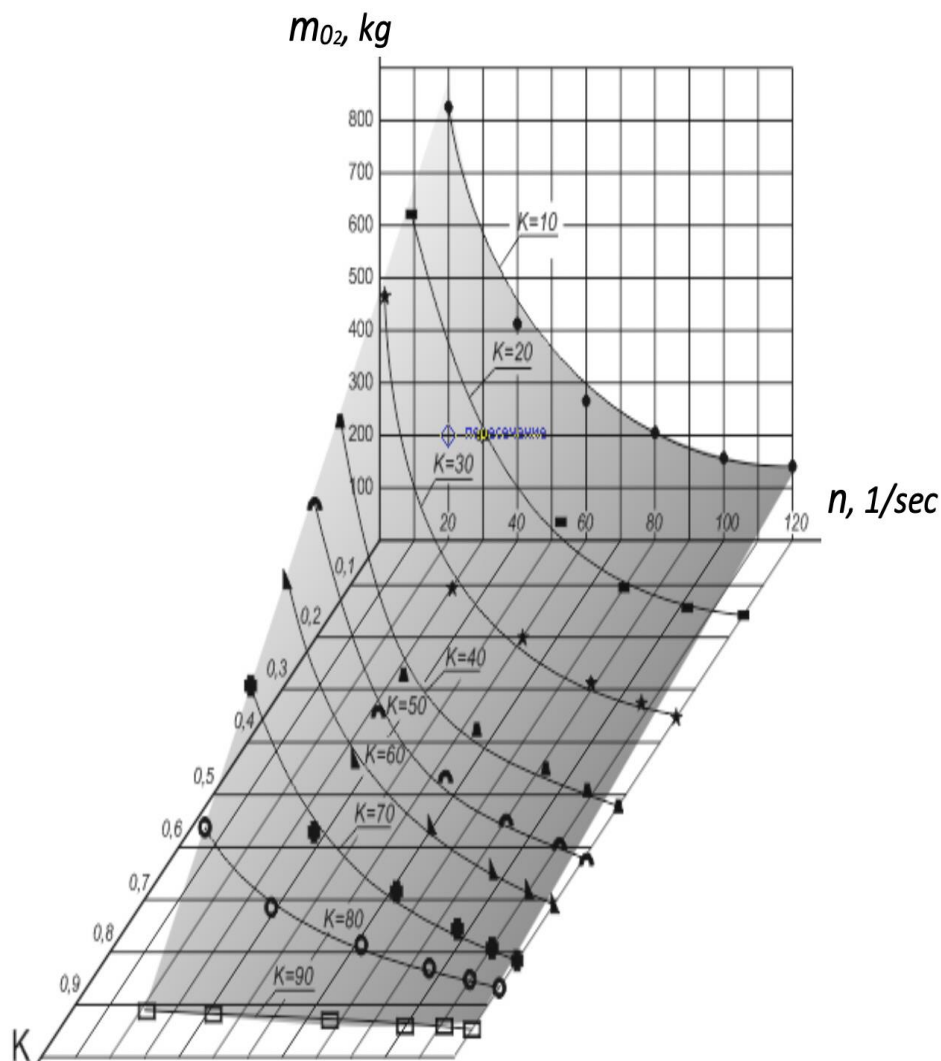
$$m_{o_2} = \frac{G \cdot p \cdot l_{el}}{n \cdot v_{el}} (1 - K) \gamma_{o_2} a_{o_2}. \quad (8)$$

This expression allows determining the oxygen mass in the spraying flow at electrodes with known parameters and spraying mode for different pulsator valve positions, i.e. the degree of overlap of the nozzle channel.

### 3.RESULTS AND DISCUSSION

The presented calculations will further serve as a basis for the construction of the nomogram.

Taking into account equation (8) and above data at electrodes spraying, the nomogram of oxygen mass dependence in the flow at electrodes spraying is constructed, Figure 5.



**Figure 5.** Nomogram for determining the oxygen mass in the spray flow depending on the degree of overlap of the nozzle -  $K$ , the pulse rate -  $n$ , for a wire with a diameter of 2 mm and a length of 100 mm, at a feed rate of 3 m/min, and the time of 10 sec.

From the nomogram, we can see that with increasing frequency of pulsation and the degree of overlap of the nozzle channel, the mass of oxygen interacting with the electrodes decreases significantly. The presented nomogram allows determining the mass of oxygen in the spray flow depending on the pulse frequency and the degree of overlap of the pulsator channel.

#### 4.CONCLUSION

The offered method allows reducing the consumption of spraying air and to reduce the burnout of alloying elements from the material which is sprayed due to a decrease in the amount of oxygen contacting with a liquid metal of electrodes.

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