# Influence of the Composition of the Gas Mixture on the Formation of Welded Coatings During the Restoration of Steel and Cast Iron Parts from Auto Tractors and Agricultural Machinery

Mitko Nikolov, Plamen Kangalov

***Abstract:*** *The composition of the gas mixture has a significant influence on the main technological parameters (roughness of the coating, frequency and duration of cycles) of the process for obtaining restorative vibro-arc welded coatings for the restoration of worn steel and cast iron parts from auto tractors and agricultural machinery. It was found that the maximum frequency of electric arc cycles with the minimum roughness of the welded coating and the minimum short circuit time are obtained at 40% CO2 for steel parts and 50% CO2 for cast iron parts.*

***Keywords****: Vibrating gas metal arc overlaying process, steel, cast iron, gas mixture, argon,* $CO_2$

## INTRODUCTION

Steel and cast iron parts represent a very large share of the restored parts of auto tractors and agricultural machinery (Kangalov P., 2019; Nikolov M., 2019). One of the high-performance and promising methods for restoring worn parts is vibro-arc welding in shielding gases and their mixtures. The composition of the protective gas environment has a significant influence on the progress of the electric arc process, the transfer of the molten metal and the formation of the welded coating [4-6]. Significant differences in the density and thermal conductivity of shielding gases determine their protective properties and conditions for arc combustion (Todorov, I. 2013).

Inert gases (argon and helium) provide the best protection of the molten metal and enable a very small depth of penetration of the base metal. Argon as a shielding gas has significantly better characteristics than helium owing to its higher density, lower ionization potential and lower heat capacity. The addition of carbon dioxide and/or oxygen to the argon reduces the spattering of molten material, improves the formation quality of the deposited layer and provides dense deposited coatings.

Carbon dioxide, argon and gas mixtures based on argon have been widely used as shielding gases. Both two-component ($Ar+CO_2$) and three-component ($Ar+CO_2+O_2$) gas mixtures are used, with the two-component gas mixtures being significantly more widespread. In the present study, two-component gas mixtures ($Ar+CO_2$) were used, which are simpler to form and effective enough to improve the quality of the deposited layer. There are not enough data and in-depth studies to determine the optimal ratio of gas mixtures ($Ar+CO_2$) for the restoration of worn parts of auto-tractor and agricultural machinery made of structural steels and cast irons in the literature (Kangalov P., 2019; Nikolov M., 2019; Nikolov M., 2014; Nikolov M., P. Kangalov, 2012; Valov, N., Valova, I., 2020; Todorov, I., 2013).

**The purpose** of the present work is to determine the influence of the composition of argon-based gas mixtures on the formation of arc-welded coatings in the restoration of steel and cast iron parts from auto tractors and agricultural machinery.

**The subject** of the study are the steel and cast-iron parts of auto-tractors and agricultural machinery subject to restoration. The subject of the study are the processes of arc welding of steel and cast iron in a gas mixture of argon and carbon dioxide.

## MATERIALS AND METHODS

The technological parameters of the overlaying process have significant importance for transferring the molten metal and forming a high-quality vibratiry iverlay on restored steel and cast iron parts from automotive and agricultural machinery.

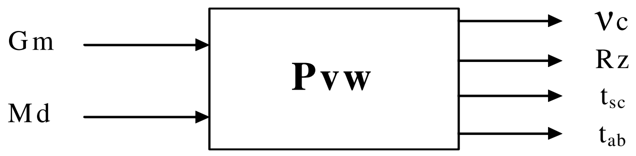


**Fig. 1** Cybernetic model for vibrating gas metal arc overlaying process: Gm – composition of gas mixture; Md – material of the part; $\nu_c$ – frequency of electrode cycles; $t_{sc}$ - short circuit time; $t_{ab}$ - arc burning time

For the input parameters of the model for studying the vibratory overlaying process in gas mixtures, the following were chosen (Fig. 1):

- Gas mixture composition (Gm);
- Material of the part (Md).

The main criteria for evaluating the quality of the vibratory overlaying process on steel and cast iron parts in argon and CO2gas mixtures are:

- Frequency of electrode cycles ($\nu_c$);
- Roughness of the overlay (Rz).

Auxiliary parameters used include:

- Short circuit time ($t_{sc}$);
- Arc burning time (tab).

The overlaying of samples to study the influence of gas mixture composition on the formation of the overlaying process is performed on a welding setup with a vibratory electrode apparatus "ENTON-60" equipped with an axial non-resonant vibrator, powered by an IZA-G500 current source. The gas mixtures are supplied to the setup from argon and carbon dioxide bottles, with the mixture composition being adjusted using a special gas mixer. The change in gas mixture composition during vibratory overlaying for steel parts is performed according to the following scheme for $CO_2$ content in the mixture: 0, 10, 20, 30, 0, 60, 80 and 100 %. For cast iron parts, the change in $CO_2$ content starts from 0 % and goes up to 100 % in increments of 10 %.

The overlaying in argon and $CO_2$ gas mixtures is performed on experimental models of steel St45 and grey cast iron ENGJL-200 with a diameter of 50 mm and a length of 250 mm, which correspond to the modal values of size and mass of real parts subject to restoration from automotive and agricultural machinery. This is because the most widely used construction steels and cast irons are St45 and grey cast iron ENGJL-200, and the past subject to restoration are those with a diameter of 50 mm, a width of restored flange of 40 mm, and a mass of 3,5 - 4 kg.

Five flanges with a width of 40 mm are overlaid on each sample using an electrode wire Np30HGSA with a diameter of 1.6 mm under the following regime: working electrical voltage of 20V, electrical current of 150 – 180 A, amplitude of electrode vibrations for steel samples $\lambda$ = 1.5 mm, and for cast iron samples $\lambda$ = 1 mm; speed of overlaying and for both materials 1.26 m/min; speed of electrode wire feed 2.3 m/min; step of overlaying 3 mm/tr; electrode wire exit 15 mm; frequency of vibrations 46.7 Hz and gas flow rate 15 l/min; angle of the arc root 450, angle of electrode wire deflection in the vertical plane 300, and in the horizontal plane 150.

The study of the vibratory overlaying process is accompanied by recording and noting the working electrical voltage and current. Suitable shunts are included in the charging circuit of the vibratory apparatus to measure and record the current. The dynamics of these parameters are recorded using an analog-to-digital converter from National instruments model NI USB 6210. The oscillograms of the process are recorded in real time using the software product "Lab View". For each change in gas mixture composition from argon and carbon dioxide and the material of the electrode wire, three recordings are performed, and the average values of the output parameters are determined. The recorded data are processed using the software product Microsoft Office Excel. The obtained data for electrical parameters from oscillography of the vibratory process are processed using known statistical methods.

The height of the irregularities on the profile of the overlaid flanges (roughness of the overlay) is measured using a special indicator device with an accuracy of 0.01 mm. For each overlaid flange and each attempt, 30 measurements are made at the peaks and troughs of the overlay layer, distributed in three equal section of 120 with 10 measurements in each section. The average value of the irregularities on the profile of each overlaid flange is calculated using the formula (Todorov, I., 2013):

$$Rz = \frac{1}{n}\left(\sum_{i=1}^{n} h_{i\max} - \sum_{i=1}^{n} h_{i\min}\right), 10^{-2}\,mm. \qquad (1)$$

**RESULTS AND DISCUSSION**

Based on the processed data, the following dependencies have been obtained between the composition of the gas mixture ($Ar+CO_2$) and the formation of vibratory overlaid coatings for the restoration of steel and cast iron parts: frequency of electrode cycles vc, short circuit time ($t_{sc}$), arc burning time (tab), and height of irregularities on the profile (Rz) of the overlaid coating (Fig. 2 - Fig. 5).

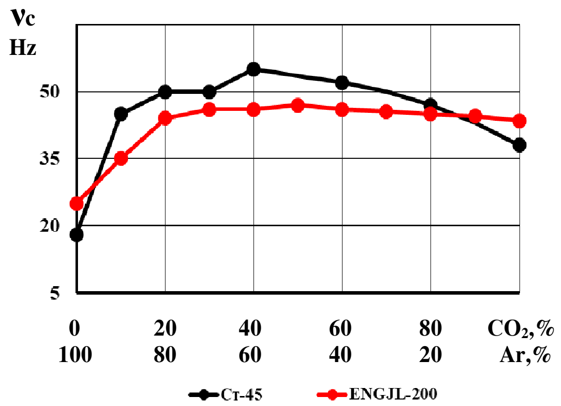


**Fig. 2** Influence of the composition of the gas mixture ($Ar+CO_2$) on the frequency of cycles ($\nu_c$) in the vibrating arc welding of steel and cast iron parts

Frequency of electrode cycles for the studied gas mixtures (Fig. 2) is in the range of 18 – 55 Hz for steel parts, whoch indicates a fine droplet transfer of the electrode metal, and 25 – 47 Hz for cast iron parts, where the droplet size is larger. With an increase in the amount of $CO_2$ in the gas mixture, the change in the frquency of cycles of the vibratory arc process has a complex character, initially incrwasing rapidly for both materials, reaching a maximum at 40 % $CO_2$ of 55 Hz for steel St45 and 47 Hz at 50% CO2 for cast iron ENGJL 200,, and then decreasing again.

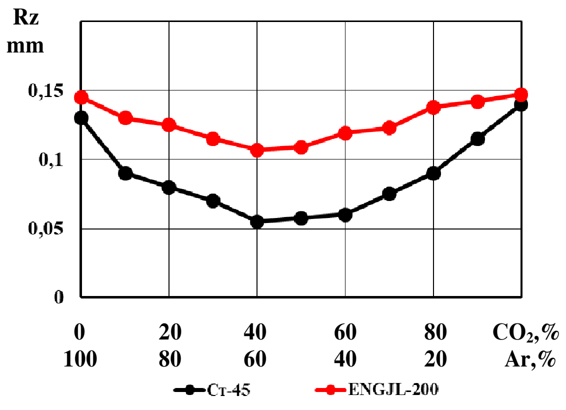


**Fig.3** Influence of the composition of the gas mixture ($Ar+CO_2$) on the roughness of the welded layer (Rz) during vibrating arc welding of steel and cast iron parts

Excluding mono-rotection at 100% Ar and $CO_2$, throughout the entire range of $CO_2$ increase, the cycle frequency during vibratory overlaying of steel parts is 5 – 10 Hz higher than during vibratory overlaying of cast iron parts. With mono – protection of 100 % Ar and $CO_2$, an inversion is observed, where the cycle frequency is 6 – 7 Hz higher during overlaying of cast iron parts compared to steel parts (Fig. 2).

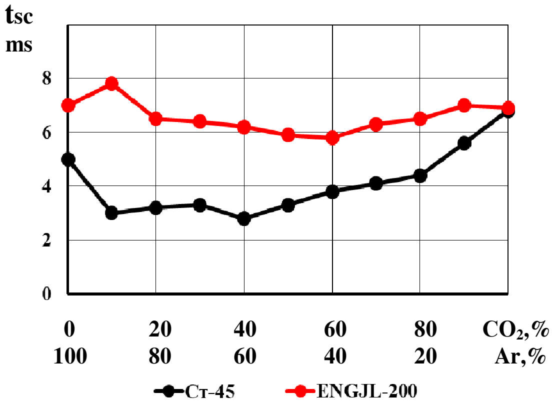


**Fig.4** Influence of the composition of the gas mixture (Ar+$CO_2$) on the time of short circuit (tsc) in the vibrating arc welding of steel and cast iron parts

The composition of the gas mixtures also significantly affects the formation of the overlaid layer and the roughness of the coating. Minimum roughness during vibratory overlaying of steel and cast iron parts is obtained at 40 % $CO_2$ content, 0.055 mm for steel and 0.107 mm for cast iron, respectively, after which it increases again (Fig. 3).

The short-circuit time is an indicator for evaluating the progress of the vibro-arc process and the transfer of the electrode metal. (Fig. 4). With a short-circuit time, a maximum frequency of cycles vc and small droplet transfer is obtained, which provides better formation of the welded metal and less roughness of the coating (Fig. 3).

During overlaying in a 100 % Ar and 100 % $CO_2$ environment, the roughness is almost the same, but in both cases, the roughness is greater than that obtained during vibratory overlaying in a gas mixture with 40 % $CO_2$. With an increase in the $CO_2$ content in the gas mixture, the roughness of the overlaid coating increases for both steel and cast iron parts.

With an increase in the $CO_2$ content in the gas mixture (Ar +$CO_2$), the roughness of the overlaid coating changes insignificantly by 0.04 mm for cast iron parts and significantly by 0.09 mm, more than twice, for steel parts during vibratory overlaying.

The indicator for assessing the progress of the vibratory process and the transfer of the electrode metal is the short circuit time (Fig. 4). With a short circuit time, a maximum frequency of cycles vc and fine droplet transfer are obtained, ensuring better formation of the overlaid metal and smaller roughness of the coating (Fig. 3).

The minimum value of the short-circuit time is obtained at 40 % $CO_2$ for steel parts, and at 60% $CO_2$ for cast iron parts, after which it icreases and reaches its maximum at 100 % $CO_2$ (Fig. 4).

During vibratory overlaying of cast iron parts, the short circuit time is always greater than that for steel parts, ranging from 2 ms to 4 ms, which explains the more difficult ignition of the electric arc during overlaying of cast iron parts. The short circuit time has a complex character. With an increase in the amount of $CO_2$ in the gas mixture based on argon (Fig. 4), a continuous increase is observed, with a minimum at 60 % $CO_2$ and a maximum at 90 % $CO_2$ in the gas mixture (Fig. 4).

The arc burning time has significant importance for droplet formation and transfer of the electrode metal and the formation of the overlaid layer. The values of the arc burning time (Fig. 5) for cast iron parts remain consistently smaller than those for steel parts after 20 % $CO_2$.

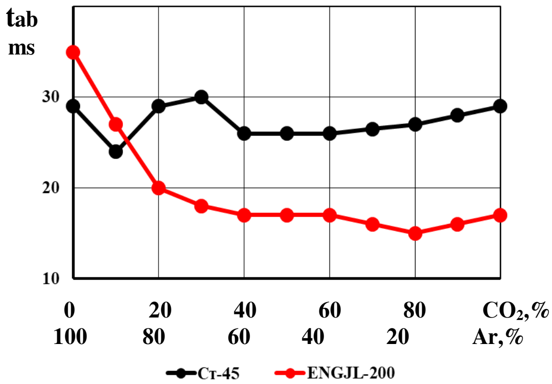


**Fig.5** Influence of the composition of the gas mixture (Ar+$CO_2$) on the arc burning time (tab) during vibrating arc welding of steel and cast iron parts

The change in the arc burning time (Fig. 5) in dependence on the increase in $CO_2$ in the gas mixture is significant for cast iron parts in the range up to 40 % $CO_2$, while for steel parts it has a variable character with increase and decrease. In the range 40 – 100 % $CO_2$, the change in the arc burning time is insignificant for steel and cast iron parts throughout the entire range.

**CONCLUSIONS**

1. The composition of the gas mixtures (argon and carbon dioxide) has a significant influence on the progress of the vibratory process and the formation of the restorative vibratory overlaid coating during overlaying of steel and cast iron parts.
2. The maximum frequency of electrode cycles at the minimum roughness of the overlaid coating and the minimum short circuit time are obtained at 40 % $CO_2$ for steel parts and 50 % $CO_2$ for cast iron parts.

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