Reconditioning of belt conveyor details by vibrating arc overlaying process

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Abstract. The recent paper presents a possibility about reconditioning of rollers and axes from belt conveyors through vibrating arc overlaying process in shielding mixtures of Ar and CO₂ with increased frequency of vibrations of the electrode wire. Work pieces made of steel 45, with dimensions of 50 mm diameter and 250 mm length, were selected for the object of this research. The working regime of overlaying process consists of voltage of 20V, current of 150-180, vibrating amplitude of 1,5 mm, overlaying speed of 1,26 m/min, wire feeding rate of 2,3 m/min, wire electrode outlet of 15 mm and overlaying step at 3 mm/min⁻¹. The shielding mixture consists of 60% Ar + 40% CO₂ fed at rate of 16 l/min. A single factorial experiment was conducted by selecting a wire electrode vibrating frequency as the main variable. The parameters of the arc vibrating process were accepted as criteria by establishing a cybernetic model.

It is established that vibrating frequency at rate of 125 Hz responding to the highest duty cycles rate, the shortage of duty cycle and arc burning time length as well as it corresponds to the smaller droplet size and minimal sparkling of molten metal. The durability of the reconditioned rollers in this way and the floating bolts are 5-times higher than new produced ones. The inner roller surface, overlaid by 08Mn2Si wire electrode, possesses higher wear-resistance compared to roller reconditioned by pressing an iron bush.

Key words: belt conveyors, vibrating arc, overlaying process, rollers

1. Introduction

Belt conveyors are widely used in agriculture, industry, energy, mines and other spheres. In the process of using these conveyors, their parts are influenced by too many external factors, leading to their wear. An increase of wear-resistance of working surfaces and shortage of expenses related to spare parts, natural resources, material and energy is possible through reconditioning and it is a key to sustainable economics especially when times of crisis still exist as well as problems about saving natural resources and the protection of environment is very important [1, 3, 4, 6].

The aim of the present research is to increase the durability of the working surfaces of key elements implemented in the structural scheme of belt conveyors by vibrating arc overlaying process with increased wire electrode vibrating frequency.

2. Exposition

A major part of the details, suitable for reconditioning belongs to the group of cylindrical or rotational details. They are made of either steel or iron, possessing a higher surface hardness, accuracy
and cleanliness, as well as complex overall shape and high production cost. The wear index rate of these parts ranges from 0.5 mm to 10 mm [2, 3, 5, 7].

The object of the research are the restored parts of the belt conveyors acting as a rotating grill in central pump stations 3 and 4, working at AEC “Kozloduy”. The rotating grill is designed as a primary filter for the incoming water from the river Danube in order to cool the reactor. The working conditions are characterized by the presence of a large amount of fine abrasive sand particles into incoming water which causes an extremely fast wear mixed with an active corrosion. This type of wear is best expressed in the steel roller, bronze bushing and steel floating bolt [9].

Before initiating a process of reconditioning it is necessary to determine the structural parameters and wear index rate of the details subject to the process as it refers to the selection of an appropriate method for reconditioning. That affects to surface quality, wear-resistance and durability of the final product. According to recent trends and conceptions, the durability of the reconditioned detail should be at least equal to the same obtained by the newly-produced one [3-6, 8].

The wear index rate, character and distribution of belt conveyor details were determined in advance. The diametrical wear of the rollers on the outer surface is at average rate of 10 mm, as 33% of all rollers show wear rate up to 19 mm. 90% of the rollers lacked the bronze bushings, which led to average wear rate within 10-11 mm, as 18% of all rollers have higher wear rate on their inner diameter. The wear rate of the floating bolt is significantly lower as the average values are in the range from 1.5 to 1.7 mm. [9]

The analysis of the reasons led to such higher wear rates for outer diameter of the roller and bronze bushing showed that the selected materials for these details are not suitable for working in high-abrasive working conditions. To increase wear-resistance and durability of the roller and floating bolt, and thereby increase the durability of entire belt conveyor cleaning system, the possibilities of vibrating arc overlaying process in gas mixtures with an increased wire electrode frequency were used for applying abrasion resistant restorative coatings. For this purpose, it is necessary to carry out experiments to determine the optimal values of the process parameters. The wire electrode vibrating frequency (f), as it is an input factor at the scheme of cybernetic model (fig.1), is selected as the main variable. Increasing the frequency leads to an increase in the number of short circuits per unit time, which in turn is associated with an increase in the number of electric cycles. The number of arc cycles is directly related to the size of the electrode metal droplets passing through the column of the arc - the larger the number of cycles, the smaller the size of the droplets and vice versa. The vibration frequency varies from 25Hz to 150Hz in 25Hz increments and assumes the following values (25, 50, 75, 100, 125, and 150) during single factorial experiments.

As main criteria for evaluation of vibrating arc overlaying process is selected to be the vector of parameters of the same which includes the following items: duty cycle frequency (f_D), short circuit time length (t_ks) and arc burning time length (t_d). The overlaying of the specimens was carried out on an apparatus for welding in shielding gases with a specially developed vibration arc apparatus with an axial inertial vibrator for a continuous change of wire electrode frequency by means of a potentiometer built into a specially designed direct current source. The welding was performed on cylindrical specimens made of steel 45, having a diameter of 50 mm and a length of 250 mm, corresponding to the average dimensions and mass of the parts to be recovered [3]. Five sectors of 40 mm wide with a 1.6 mm diameter CB08G2C electrode wire were deposited onto each specimen within protective gas mixture of argon and carbon dioxide in 60% Ar and 40% CO2 composition [2]. The working regime parameters were selected in the following mode: vibrations amplitude of 1.5 mm; operating voltage of 20 V; electric current of 150-180 A; loading speed 1.26 m/min; electrode wire feed rate 2.3 m/min; welding step 3 mm/min; 15 mm electrode wire outlet; shielded gas consumption 15 l/min.

The study of the process of vibrating arc welding with increased wire electrode vibrating frequency is accompanied by real-time recording of the process parameters - frequency of the electric cycles, the electric voltage and the magnitude of the current. Appropriate shunts were included for measuring and recording the amount of current in the vibration circuit of the vibrating apparatus. The
dynamics of changing these parameters were recorded using NATIONAL INSTUMENTS NI USB 6210 analog-to-digital converter. The process waveforms were recorded using the Lab View software. For each change in the frequency of vibration of the electrode wire, 3 entries were made, determining the average values of the output parameters. The recorded data was processed using the Microsoft Office Excel software product. The obtained data for the output parameters of the oscilloscope of the vibrating arc process and micrometry of welded specimens were processed by known statistical methods.

Based on the statistically processed data from the oscillograms of deposited layers, graphical dependences were obtained to evaluate the influence of the wire electrode vibrating frequency onto duty cycles frequency and parameters of the welded coating formation (Fig. 2 and Fig. 3).

After processing the results of recorded waveforms, it was found that when frequency of vibrations increases, the frequency of the electric cycles also increases as the functional dependence is shown in Fig. 2. The influence caused by wire electrode vibrating frequency has an extreme character reaching a maximum cycle frequency of 76.3 Hz at vibration frequency of 125 Hz. As the vibration frequency increases further, a sharp decrease in the cycle frequency is observed. Achieving maximum value is a prerequisite for improving the vibration process in terms of finer drop transfer of the electrode metal, more uniform formation of the individual seams, which in turn is a prerequisite for obtaining a fine-grained structure and higher hardness of the deposited metal [2, 3].

Increasing the frequency of arc cycles influences over their duration, i.e. results in the shortening of time vector parameters - short circuit and arc burning time lengths. Figure 3 shows a graph of the variation of these parameters depending on wire electrode vibration frequency. The graph shows an increase duty cycles number due to gradual decrease in both - short circuit and arc burning time lengths. The short-circuit time affects process stability and the degree of atomization of molten metal. Therefore, the shorter the short-circuit period is, the more stable the electric arc is and the lower the electrode metal losses are. The arc burning time characterizes the enhancement of droplets from the moment of contact of the electrode wire to the metal surface until detachment from wire electrode tip. Therefore, the shorter arc burning time for each cycle is, the smaller the droplet size is, which improves the fusion conditions between the parent and feed metal and the formation of uniformly deposited layers with a fine-grained structure.

After processing the results, it was found that the alteration of the short circuit and arc burning have an extreme character. Minimum values for both times are obtained at rate of 125 Hz wire vibration frequency. This frequency correlates with Fig. 2, which produces the highest frequency of arc cycles. The arc burning time at 125 Hz vibration frequency is reduced almost twice compared to the 25 Hz vibration frequency having values of 9.8 ms and 18 ms respectively. Consequently, the size of metal droplets and level of burning of the alloying elements are reduced in the same order. Spreading the electrode metal during the process of overlaying in a shielding gas environment is essential for forming a high-quality deposited layer with the required purity. There are various methods for reducing the degree of scattering and burning of the electrode metal, one of which is based on the positive influence of wire electrode frequency and its results are presented in Table 1.

Table 1. Scatter losses of molten metal during vibrating arc overlaying process in gas shielding
The results from Table 1 show that minimal possible scatter losses as well as burning of molten metal appear at wire electrode vibrating frequency of 125 Hz and with the value of 8%. The highest percent losses at rate of 25 Hz can be explained with higher rates of short-circuit and arc burning time lengths mentioned above. With the higher rates, the droplets size increases too and the stability of the process worsens. Another reason is the intensive dissolution of oxygen from shielding mixture which leads to carbon burning and forming of oxides with higher hardness. During separation of gas fumes through the droplet of molten metal, reactive forces are formed which prevent it from separating from the tip and increase its mobility, especially in the case of increased carbon content. This results in an increased velocity of the metal droplets at the moment of their separation from the tip of the electrode wire and their movement in different directions.

Several options were laid down to restore the worn work surfaces of the roller and floating bolt. The outer surface of the roller was reconditioned by vibration arc overlaying with usage of electrode wire 08Mn2Si with a diameter of 1.6 mm, vibration frequency of the electrode wire 125 Hz, while the loaded metal layer was obtained in a protective environment of 60% Ar and 40% CO2 [2] in order to reduce carbon burning and obtain better formation. The working regime includes voltage of 18-20 V, electric current of 150-180 A, welding speed at rate of 0.4 m/min, electrode wire feed rate 2.3 m/min, welding step 3.5 mm/min-1, electrode wire outlet 15 mm and gas flow 15 l/min.

Two technological variants were used to restore the inner surface of the roller. The first one consists of vibrating arc overlaying, but the second one - by replacing bronze bushing with sleeve made of cast iron 25. The first method was performed within following working conditions: wire electrode 08Mn2Si with a diameter of 1.2 mm, vibration frequency of the electrode wire 125 Hz, while the loaded metal layer was obtained in a protective environment of 60% Ar and 40% CO2; operating voltage 18-20 V, electric current 100-120 A, overlaying speed at rate of 0.6 m/min, wire feed rate 2.3 m/min, welding step 2.5 mm/min-1, electrode wire outlet 15 mm and gas consumption 15 l/min. Two types of electrode wire 08Mn2Si and DUR 350 with a diameter of 1.2 mm and a protective mixture of 60% Ar and 40% CO2 were used for the restoration of the floating bolt with the following parameters: operating voltage 18-20 V, electric current size 100-120 A, welding speed 1 m/min, wire feed rate 2.3 m/min, welding step 2.5 mm/min-1, electrode wire outlet 15 mm and gas flow 15 l/min. The hardened parts were hardened in HDTV to a hardness of 30-35 HRC.

After six months of operation, corresponding to one inter-service period, measurements of reconditioned details were made to determine their wear obtained during exploitation and the results of the measurements are presented in Table. 2. It has been found that the amount of wear of reconditioned rollers and floating bolts is on average five times less than that of new parts over the same service life.

### Table 2. Wear index rate of roller and floating bolt, reconditioned by vibrating arc overlaying process within gas shielding mm

| № of specimen | f, Hz | Mass before deposition, g | Mass after deposition, g | Difference ΔG, g | Spatter losses ψ, % |
|---------------|------|--------------------------|-------------------------|-----------------|-------------------|
| 1             | 25   | 1700                     | 1729                    | 29              | 47                |
| 2             | 50   | 1694                     | 1737                    | 43              | 21                |
| 3             | 75   | 1690                     | 1735                    | 45              | 18                |
| 4             | 100  | 1712                     | 1761                    | 49              | 10                |
| 5             | 125  | 1782                     | 1832                    | 50              | 8                 |
| 6             | 150  | 1725                     | 1773                    | 48              | 11.7              |

The wear of the inner bore of the roller with a crimped cast iron sleeve is of greater value than the welded wire Sv 08G2C due to the higher rigidity of the latter. The recovered floating bolts have less wear on the surface of those bolts overlaid with DUR 350 at the same initial hardness.
3. Conclusions

1. The durability of rollers and floating bolts, reconditioned by vibrating arc overlaying process is five times higher than the newly produced ones.

2. The wear index rate of floating bolt reconditioned with wire electrode DUR 350 is less than one reconditioned with 08Mn2Si within same rate of surface hardness.

3. The reconditioned with 08Mn2Si inner surface of the roller possesses higher wear-resistance compared to roller reconditioned by tapping an iron bushing.

4. References

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