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STUDY ON HARDNESS AND WEAR RESISTANCE OF LAYERS OVERLAYED USING ELECTRODES WITH NANO-MODIFIED COATING

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ABSTRACT

Developed is innovative manufacture technology for electrodes nano-modified with TiN, Al_2O_3, SiC, TiCN+C, TiN+Cr, and TiCN purposed for weld overlay of wear resistant surface layers. Test samples are cladded using the manufactured electrodes. Vickers hardness and wear resistance of the overlayd metal are measured The resulting variations of hardness and wear resistance are analyzed in relation with the nature of nano-modifier used. The application area of nano-modified electrodes is for both preventive and repair weld overlay.

Key words: electrode, manual arc welding, nano-modifier, weld overlay, overlayed layer, Vickers hardness, wear resistance

INTRODUCTION

Arc welding is a technology appropriate to increase the wear resistance of surfaces of parts and tools. The weld overlay can be purposed for prevention or repair. The process is especially efficient when different modifying additives are introduced in the weld overlay metal. The additives can be introduced via the coating of the welding electrodes.

The recent study presents an innovative technology for manufacture of electrodes for arc manual welding containing different types of nano-particles (modifiers) in the coating. Herein are also presented the results from the testing of hardness and wear resistance of claddings overlayed using nano-modified electrodes.

The review of the reference literature available reveals numerous studies on the effect of titanium-containing nano-particles on the technical characteristics of the metal after weld overlay. Most studies use titanium dioxide, titanium, titanium carbonitride [1],and silicon carbide [2] as nano-modifiers. It is found that the increased quantities of titanium-containing inclusions lead to changes in the micro-structure of the metal thus improving its mechanical properties (hardness, wear resistance) [3]. The increased concentration of titanium in the weld overlayed metal increases the concentration of titanium in these inclusions too. [4]. Examined is the effect of titanium [5] on the properties of the weld overlayed metal at 1.4% and 2% levels of manganese. The mechanical properties of the weld overlayed metal are improved [6-10], especially at medium concentrations of nano-particles, which is explained with the increased level of acicular ferrite and the finer microstructure.

The significantly improved mechanical properties, such as high hardness and toughness, are probably due to the fine grain microstructure and redistribution of internal stresses resulting from the added substances in the form of nano-powders with predominant particle size distribution measuring several tens of nanometers [11,12].

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DEVELOPMENT AND MANUFACTIRE OF NANO-MODIFIED ELECTROLDES FOR WELD OVERLAY

The nano-modified electrodes for weld overlay are developed based on electrode type IZA-E300. It belongs to the group of electrodes for weld overlay of layers with higher requirements for wear resistance. [13]

Materials for the coating of the electrodes delivered are graded according to the technical requirements for each of them individually. Preliminary chemical analysis and granulometric analyses are carried out. Used is potassium water glass with content as per the requirements of the technical specification. Selected is electrode wire with diameter Ø3.25 and length 450mm.

The materials are dosed in accordance with the formulation for manufacture of electrodes type IZA-E300. Nano-materials are input at a certain point in the implementation of the technology, taking into account the specific particle size of material.

The dry homogenization is carried out manually with a blender. The nano-materials for each sample are added immediately before blending. The wet homogenization is carried out in "S" blender with volume up 2,5 kg.

First, the sample coating is dry blended, and then water glass is added in trickle. The coating thus prepared is poured into a suitable container and fed to the extrusion press.

The technological extrusion press (Fig.1) is set for electrodes with dimensions Ø3.25/450 mm.

Fig. 1. Process of extrusion

The extruded electrodes are passed through the trimming device. The concentricity of the coating is checked using a tool that is calibrated for the particular diameter. The first and the last electrode are removed because since their coating is usually incomplete or uneven (Fig. 2).

Fig. 2. Extrusion line

The ready electrodes are arranged on grids and are dried in air and in drying furnace.

The classification of nano-modified electrodes according to the amount and the type of nano-modifier is shown in Table 1.

Table 1. Classification of electrodes

Sample No	Nano modifier	Quantity, %
1	Reference electrode (IZA-E300)	-
2	TiN	A
3	Al_2O_3	A
4	SiC	A
5	TiCN+C (coated with carbon)	A
6	TiN+Cr (coated with chromium)	A
7	TiN	A/2
8	TiCN	A/2
9	Al_2O_3	A/2
10	SiC	A/2
11	TiN+Cr (coated with chromium)	A/2

where A is the basic quantity of nano-modifier used.

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EXPERIMENTAL STUDY OF LAYERS WELD OVERLAYD USING NANO MODIFIED ELECTRODES

The characteristics of the experimental nano-modified electrodes are assessed on steel S 235JR plates with dimensions 250x400x20mm (according to Specification ISO/DIS 15614-7 for weld overlay) with three-layer weld overlay cladding.

Assessment of hardness of the weld overlayed metal

After weld overlay, half of the overlayed surface (OS) is polished, as is shown in Fig. 3.

Fig. 3. Cladded and polished sample

The hardness measurements are carried out according to Vickers $HV_{15/15}$ in eight points as per the diagram shown in Fig. 4.

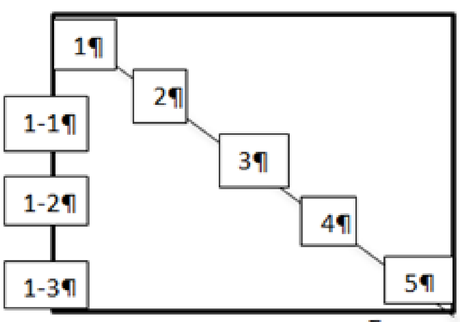

Fig. 4. Diagram of points for measurement of hardness

The maximum deviations from the measured values are eliminated and the average measured values of hardness are shown in Table 2.

Table 2. Hardness of CS ($HV_{15/15}$)

Sample No	Average value of hardness $HV_{15/15}$.	%
11	644.9	56
10	570.6	38
2	485.9	18
6	476.0	16
7	462.0	12
3	436.1	6
8	428.1	4
9	427.9	4
4	412.4	0
1	412.1	0
5	371.1	-10

Estimated is the percentage change of hardness of each sample related to the basic Sample No 1. The highest percentage increase (56%) is achieved in Sample No 11 where the nano-modifier introduced with the coating of the electrode is titanium nitride coated with chromium.

There is a substantial increase of hardness (38%) achieved in Sample No 10 where the nano-modifier introduced is silicon carbide. Most samples (No 9, 8, 3, 7, 6, 2) with nano-modified overlayed surface also exhibit increased hardness in the range from 4% to 18%.

The variations of the average hardness depending on the type of nano-modifier introduced is shown in Fig. 5.

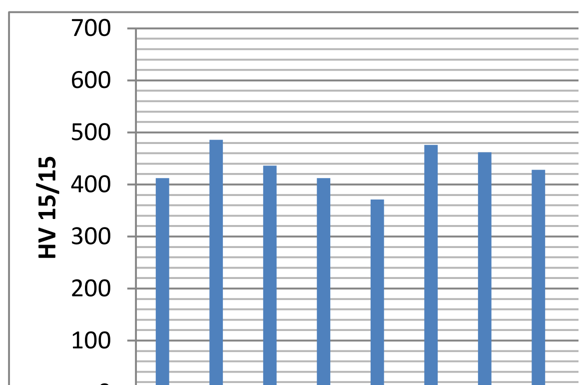

Fig. 5. Vickers hardness of OS depending on the type and the concentration of nano-modifier introduced

Some experimental results for hardness of samples with weld overlayed nano-modified surfaces are presented in [14]. There is a certain

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dissipation of the measured values for hardness. The comprehensive ultrasound examinations proved that there are a lot of imperfections in the weld overlayed layer that can explain the dissipations of the values for hardness, and in the performance of the cladded layer, respectively.

The authors attempted to diagnose the discontinuities using surface wave method similar to that described in [15]. Registered is a significant deviation from the behavior of the wave and is suggested transformation of Rayleigh wave in another type of wave. The subsurface imperfections can inflict local deformations at significant contact interactions. They can cause dissipation of measurement results when the wear of the overlayed layers is assessed in the recent study .

Assessment of wear resistance of the weld overlayed metal

The authors assess the wear resistance of claddings using our own methodology described in [16, 17]. It consists in measurement of the mass wear of samples after a number of wear cycles and estimation of wear intensity and wear resistance for the travelled path of friction. The comparison upon the parameter wear resistance is made under invariable test conditions.

The methodology for testing of wear resistance is based on measuring the integral (total) loss of mass of the test sample at exactly the same conditions of contact interaction of the sample with the abrasive surface: normal loading, sliding speed, contact area, road of friction, dimension and hardness of abrasive particles. By measuring the mass wear using the developed methodology are estimated the rate of mass wear and the intensity of mass wear resistance.

The samples for the testing of wear resistance are cylindrical with diameter 8mm and length equal to the thickness of the cladded plate. The cylinders are cut out using water jet abrasive technology in order to avoid any possible deformations and stresses from undesired heating. The method for testing is implemented using the device shown in Fig. 8, which operate under kinematic scheme "finger-disc" [23].

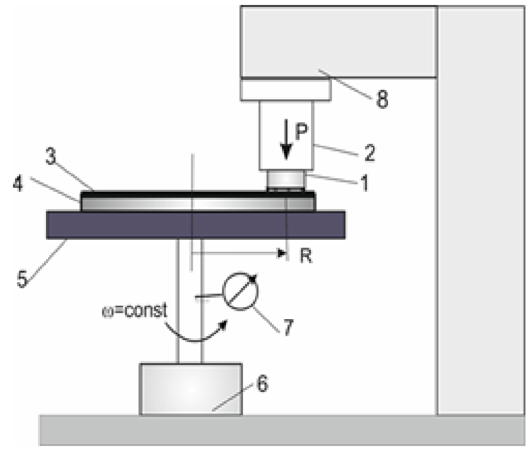

Fig.8. Scheme of tribotester for fixed abrasive wear study of coatings

The results from the testing for wear resistance are shown in Table 2. As is seen, the best results are achieved in Sample 11 where the increased hardness (with 56% compared to the reference sample) leads to almost 70% increase of wear resistance. Samples 7, 8, and 10 exhibit wear resistance close to that of the reference sample. The rest samples 2, 3, 4, 5, 6, and 9 exhibit lower wear resistance compared to the reference Sample 1.

Table . Test results of wear resistance

Sample No	Wear m, mg	Wear resistance I_h
1	110.5	$0.44.10^6$
2	146.4	$0.33.10^6$
3	112.7	$0.43.10^6$
4	139.5	$0.35.10^6$
5	131	$0.37.10^6$
6	138.6	$0.35.10^6$
7	97.9	$0.49.10^6$
8	92.2	$0.52.10^6$
9	125	$0.40.10^6$
10	94.4	$0.51.10^6$
11	64.4	$0.75.10^6$

Figure 9 illustrates graphically the results from testing for wear resistance of weld overlayed layers using nano-modified electrodes.

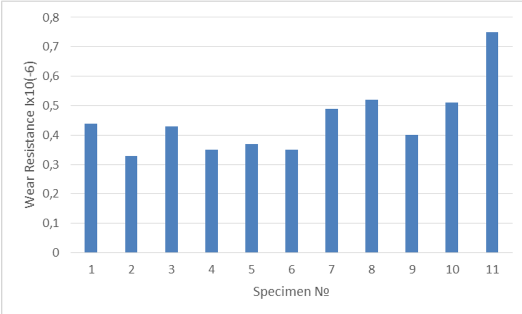

Fig. 9. Wear resistance of overlayed layers using nano-modified electrodes

CONCLUSIONS

1. Developed is innovative technology for manufacture of nano-modified electrodes for manual arc welding belonging to the group of electrodes for weld overlay of wear resistant surface layers, and trial amounts thereof are manufactured in experimental conditions.

3. Manual arc welding of steel plates S 235JR has been carried out. The welded samples are polished and Vickers hardness is measured.

4. A significant increase of hardness, correspondingly with 56% and 38%, is observed in Samples No 11 and No 10, compared to the reference sample. The overlayed metal in Sample No 11 is nano-modified with titanium nitride coated with chrome, and that of Sample No 10 is nano-modified with silicon carbide.

6. Comparative study of samples for wear resistance is carried out using the method of accelerated surface wear with fixed abrasive. The highest wear resistance (70% higher than that of the reference sample) is achieved in the layer overlayed using electrode Sample No 11.

7. There are certain deviations in hardness and wear resistance that are possibly due to the presence of some sub-surface imperfections revealed through ultrasound non-destructive testing.

8. The nano-modfication of surfaces through weld overlay with electrodes for manual arc welding results in considerable increase of hardness and wear resistance of the overlayed layers modified with nano sized particles of TiN coated with Cr.

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