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# EXPERIENCE IN APPLICATION OF ELECTRIC ARC SURFACING WITH FLUX-CORED WIRE AT THE ENTERPRISES OF UKRAINE

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The surfacing using flux-cored wire finds a wide application in many branches of industry and, first of all, in the repair works. At the present time the largest manufacturer of flux-cored wires for surfacing in Ukraine is the enterprise «TM. VELTEK». In the present work the developments of this enterprise and the experience of their use in repair surfacing of rolls of rolling stands, CCM rollers, wheel cranes and also the rollers of straightening machines and critical parts of hydraulic supports of mining equipment are described. 20 Ref., 3 Tables, 7 Figures.

***Keywords:*** *arc surfacing, flux-cored wires, repair works, wear resistance, hardness, microstructure, increase in service llife*

The first flux-cored wires for electric arc surfacing were developed in the 1950s at the E.O. Paton Electric Welding Institute [1]. In the following years due to versatility, simplicity and efficiency of manufacturing technology this type of electrode materials for arc surfacing found a wide spreading in different branches of industry [2–4]. The majority of grades of flux-cored wires of different purpose were developed at the PWI and manufactured by the PWI Experimental Production and the PWI Pilot Plant of Welding Materials [5–7]. In the 1990s and the following years the production of flux-cored wires for welding and surfacing in Ukraine was mastered by a number of new companies. Also the flux-cored wires of foreign companies appeared at the market of Ukraine.

In this article the experience of application of flux-cored wires in different branches of industry is described, which are developed and manufactured by Company «TM.VELTEK».

**Surfacing of rolls of rolling stands.** For surfacing of steel rolls of rolling stands of different purpose the repair services of metallurgical plants of Ukraine apply the electric arc surfacing using flux-cored wires PP-Np-35V9Kh3SF, PP-Np-25Kh5FMS, PP-AN132, PP-AN147 etc. [1, 2, 6]. The main causes of failure of steel rolls of hot rolling is the oxidation, abrasive wear and thermal fatigue. To a large extent such wear of the working surface of the roll is connected with the structural state of the metal and the morphology of its structural components [8, 9].

For surfacing of rolls of blooming stands «TM. VELTEK» proposed flux-cored wire Veltek-N505 (alloying system Fe–C–Si–Mn–W–Cr–Mo–Ni–V). The existing methods of tests on thermal resistance, heat resistance and wear at high temperatures can not provide a reliable determination of resistance of deposited metal of a particular type directly under the conditions of rolling. The field tests of rolls of rolling mill NZS-730 of the workshop «Blooming-1» at the Krivoy Rog Mining and Metallurgy Plant «Krivorozhstal» were performed deposited with flux-cored wires PP-Np-35V9Kh3SF and Veltek-N505.

The averaged values of the relative wear resistance and relative resistance to fire crack formation in deposited rolls of rolling mill NZS-730 are given in Table 1. As compared to wire PP-Np-35V9Kh3SF the formation and development of fire cracks in the depth of their penetration is 2–4 times reduced [10], which significantly reduces the depth of the groove during repair of rolls.

**Table 1.** Wear resistance and crack resistance of deposited rolls of rolling mill NZS-730 of the workshop «Blooming-1» at the «Krivorozhstal»

| Grade of flux-cored wire | Hardness of deposited metal *HRC* | Relative wear resistance | Relative crack resistance |
|---|---|---|---|
| PP-Np-35V9Kh3SF | 46–48 | 1.0 | 1.0 |
| Veltek-N505 | 50–54 | 1.3 | 2.0 |

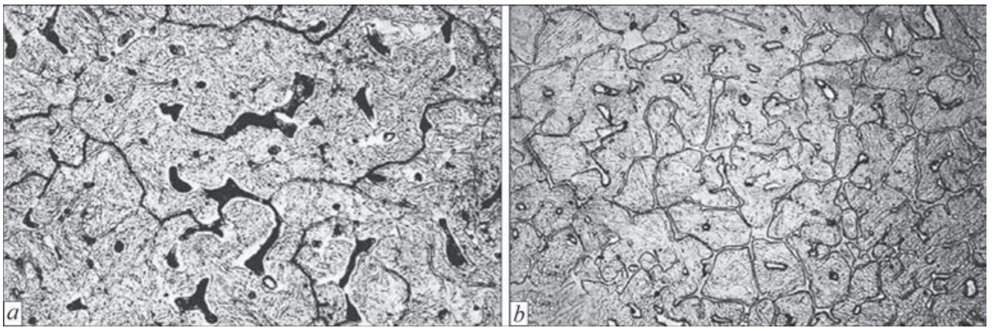

**Figure 1.** Microstructure (×500) of metal deposited using flux-cored wire: *a* — PP-Np-35V9Kh3SF; *b* — Veltek-N505

The microstructure of deposited metal of both types was investigated. The structure of metal deposited using wire PP-Np-35V9Kh3SF represents a coarse acicular martensite with the islands of residual austenite and elongated layers of carbide eutectics along the boundaries of primary austenite grains (Figure 1, *a*). In the body of grains and at their boundaries the carbides of chromium, tungsten and dispersed vanadium carbides are observed.

The metal deposited using wire Veltek-N505 has predominantly the structure of a fine-acicular martensite with the fringes of residual austenite along the boundaries of the primary grains. Inside the grains the uniformly distributed carbides of chromium, tungsten, molybdenum and vanadium are also observed (Figure 1, *b*).

For surfacing of rolls of the first and the second stands of pipe rolling mill TPA 30-102 of the Nikopol Seamless Pipe Plant «Niko Tube» flux-cored wire Veltek-N480NT (alloying system Fe–C–Si–Mn–Cr–V–Mo–W) was proposed. The structure of metal deposited using that wire consists of a fine-acicular martensite, residual austenite at the grain boundaries and small formations in the body of grains (Figure 2). Carbide precipitates along the grain boundaries are negligible. The dispersed carbides are uniformly distributed in the grain body along their boundaries. The hardness of deposited metal is *HRC* 50–56.

The rolls of the first stand, deposited using flux-cored wire Veltek-N480NT, were removed from the mill after 5000 t rolling of pipes. The wear on the bottom of the caliber was 0.3–0.5 mm. The condition of a surface of roll calibers is satisfactory, the surface is smooth and the cracks were absent. The wear of rolls of the second stand was 1.5–2.0 mm after rolling the 8790 t of pipes. The life of rolls of the second stand was increased from 1,200 to 8,000 t of pipe rolling.

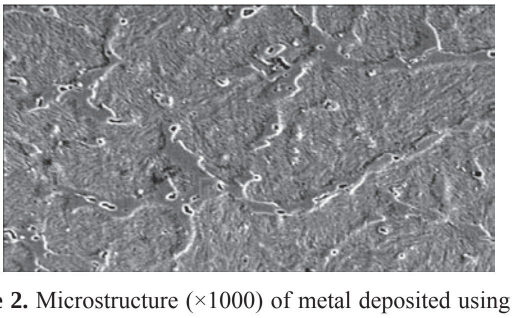

**Figure 2.** Microstructure (×1000) of metal deposited using flux-cored wire Veltek-N480NT

**Surfacing of MCCB rollers.** The domestic [11–14] and international experience shows that for surfacing of working layer of MCCB rollers the following alloying systems are mainly used: Fe–C–Cr (predominantly for straight areas of MCCB), Fe–Cr–Ni–Mo–N and Fe–C–Cr–Ni–Mo–V–Nb (predominantly for curvilinear areas of MCCB).

For surfacing of rollers of MCCB the «TM. VELTEK» proposed flux-cored wires Veltek-N470 (for submerged surfacing) and Veltek-N470G (for surfacing in the mixture of shielding gases) of alloying system Fe–C–Cr–Ni–Mo–V–Nb–N.

In the manufacture and repair of the rollers at the «Azovstal», Iliich Metallurgical Plant (Mariupol) and Novo-Kramatorsk Metallurgical Works the technology of surfacing was applied using wire Veltek-N470 of 3.0–3.6 mm diameter under fluxes AN-20 or AN-26 on a screw line using a single arc, without oscillation and with transverse oscillations. The Starokramatorsk Machine Building Plant (Kramatorsk) performed surfacing of rollers of MCCB using wire Veltek-N470G of 2.0 mm diameter in the mixture of Ar + 18 % $CO_2$.

The hardness of the deposited metal after smoothing amounts to *HRC* 44–48 and corresponded to the technical task of the customer. The structure of the deposited metal represents a low-carbon fine-acicular martensite hardenedd with dispersed carbides and nitrides (Figure 3). At the «Azovstal» the manufacture and repair surfacing with the mentioned flux-cored wires provided the treatment of the radial area with 3000 melts and the straight area with 7500 melts at the volume of one melt being 175 t.

**Surfacing of crane wheels.** For surfacing of crane wheels, as a rule, the surfacing materials are applied which provide producing the deposited metal of the type of low-alloyed steels 18Kh1G1M or 30KhGSA. However, during surfacing of heavily-loaded wheels of cranes, which operate at the metallurgical enterprises, these materials do not provide the required service life.

The increase in wear resistance of parts of the similar type can be achieved using the surfacing materials providing producing the deposited metal with the structure of metastable austenite undergoing transfor-

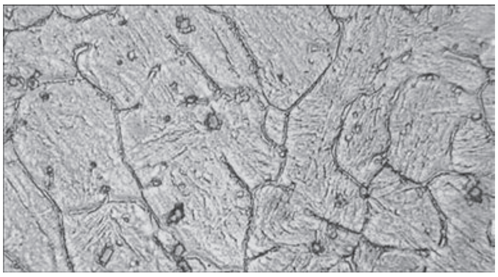

**Figure 3.** Microstructure (×1000) of metal deposited using flux-cored wire Veltek-N470 with volume fraction of δ-ferrite of 5.2 % and hardness after surfacing *HRC* 42–46

mation into martensite under the influence of deformations occurring at loading of a part in the process of service [15–18].

At the Iliich Metallurgical Plant for surfacing of the heavily loaded crane wheels it was proposed to apply flux-cored wire Veltek-N285.01 (alloying system Fe–C–Cr–Mn–Mo–V). In the deposited metal of this type the structure of metastable austenite is formed, which is considerably hardened during cold work hardening (Figure 4). After tempering at 600 °C, applied for inner stresses relieving the precipitations of dispersed carbides of chromium, vanadium and molybdenum are observed. As a result of depletion of matrix grains wtih carbon and alloying elements, the deformational martensite transformation is intensified, which leads to a significant increase in wear resistance of metal of the deposited rolling surface of the wheel. According to the data of X-ray structural analysis, on the deposited surface of the wheel after annealing the fraction of martensite is 1.5–2 times increased and amounts to about 30–35 vol.%. The hardness of metal after surfacing is *HB* 217–220 and after cold work hardening it amounts to *HB* 380–410.

According to the data of laboratory tests, in sliding friction according to the shoe–roller scheme and at the abrasive effect, the highest wear resistance was obtained in surfacing using wire Veltek-N285.01 (PP-Np-14Kh12G12MF) (Table 2). Two variants of technology for surfacing of crane wheels were realized: 1 — surfacing of ledges and rolling surface using wire Veltek-N285.01, and 2 — surfacing the rolling surface with wires Np-30KhGSA or PP-Np-18Kh1G1M and rims — with Veltek-N285.01 wire. A 3 times increase in service life of the crane wheels was achieved, which allows enterprises to reduce significantly the operating costs on the cranes.

**Surfacing of rollers of straightening machines.** The rollers of straightening machines are traditionally manufactured of steel 90Kh1 with a surface heat treatment. In the process of surfacing on steel 90Kh1 the high preheating temperature of 400–450 °C and its stable maintaining along the whole length of the part are required due to a high tendency of steel 90Kh1 to hot and cold crack formation. However, the severe conditions of operation of these rollers, especially during straightening of sheet products and rolled

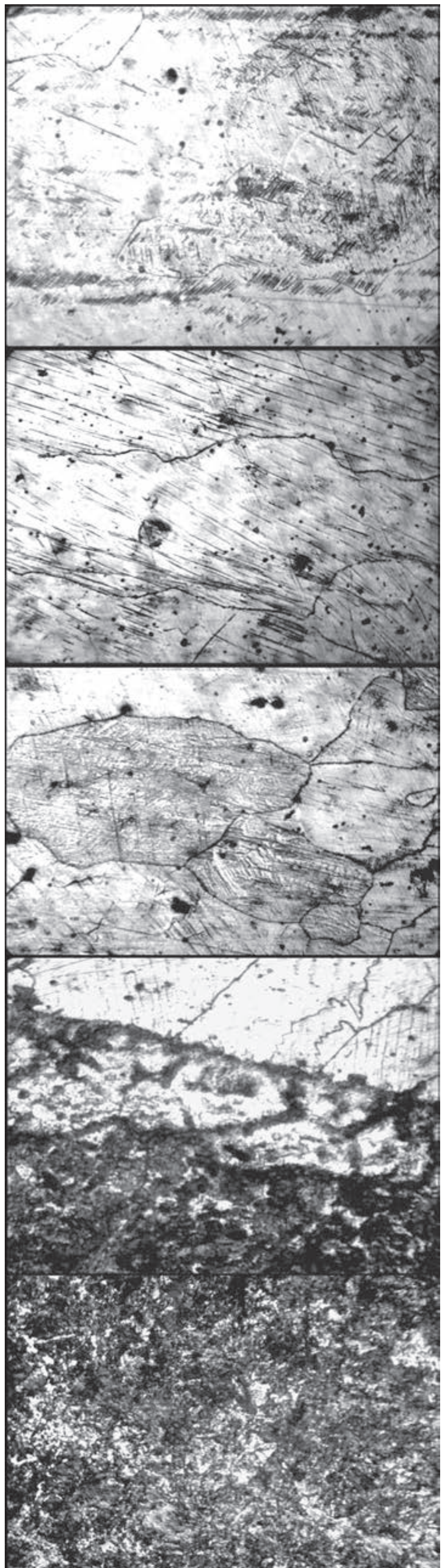

**Figure 4.** Microstructure (×550) of metal layers from the base metal surface (from top to bottom) deposited using flux-cored wire Veltek-N285.01

sections of alloyed grades of steel with a scale cause their premature failure. An insufficient resistance of straightening machine rollers of steel 90Kh1 with a

**Table 2.** Relative wear resistance of metal deposited using different flux-cored wires

| Surfacing material | Heat treatment mode | Relative abrasive wear resistance* | Relative wear resistance under the conditions of dry friction* |
|---|---|---|---|
| PP-Np-18Kh1G1M (reference) | Surfacing + annealing at 550 °C (1 h) | 1.0 | 1.0 |
| Np-30Kh10G10 | Surfacing + annealing at 550 °C (1 h) | 2.0 | 3.0 |
| Veltek-N285.01 | Surfacing + annealing at 600 °C (1 h) | 2.3 | 3.2 |
| *Determined by ratio of mass loss of the deposited metal of the reference to mass loss of the corresponding deposited metal. | | | |

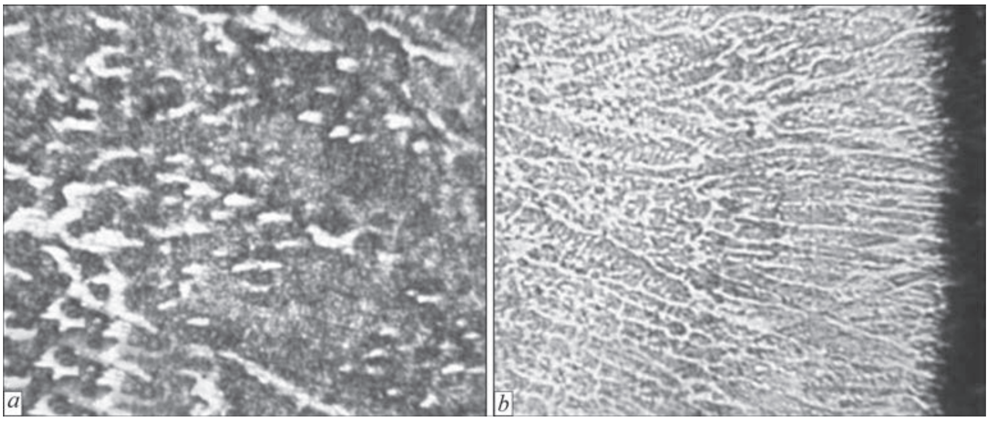

**Figure 5.** Microstructure (*a* — ×1000; *b* — ×100) of working layer metal of the roller deposited using flux-cored wire Veltek-N545

surface hardening even when a sufficiently high hardness (*HRC* 61–63) is provided, is explained by insufficient number of hardening phases (carbides, carbonitrides) in the structure of metal of these rollers and insufficient thickness of the hardened layer (from 1.5 to 5 mm). Moreover, so far nobody has repaired the straightening machine rollers of steel 90Kh1 because of a poor weldability of this steel grade.

The efficient technological solution to this problem was proposed by the Company «Vosstanovlenie» (Lipetsk) and Company «TM.VELTEK». It is proposed to manufacture rollers of heat-treated steel 40Kh and to perform their surfacing using wires Veltek-WT550.01-F (Fe–C–W–Mo–Cr–V) and Veltek-WT545-F (Fe–C–Mo–Cr–V–Ni). The hardness of deposited layer in this case is *HRC* 57–60.

The high wear resistance and hardness of the working surface of rollers is achieved by formation of martensite structure hardened by dispersed carbides and also by decrease in the structure of primary grain size by performing a process of surfacing using the wire of 2.0 mm diameter at the modes with an optimum combination of efficiency and heat input (Figure 5). The surfacing process was carried out at direct current of reverse polarity under flux AN-26p at $I_a$ = 260–280 A, $U_a$ = 30 V, $v_w$ = 28–30 m/h.

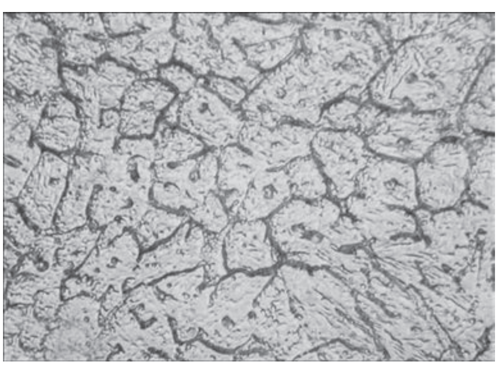

**Figure 6.** Microstructure (×1000) of metal of hardening layer deposited using flux-cored wire Veltek-N425

The rollers of straightening sheet metal machines with diameter of the barrel of 190, 230, 250 and 360 mm, restored applying the new technology provided the «Vyksa Metallurgical Plant» with 3–4 times increase in service life as compared to the new rollers of steel 90Kh1 with surface hardening. Moreover, the cost of repair of these rollers applying the new technology was less than a half of the cost of the new ones, manufactured of steel 90Kh1.

**Surfacing of rods and plungers of hydraulic power supports of mining equipment.** The rods and plungers of hydraulic power supports are subjected to chrome plating during manufacturing process. During operation process they are subjected to corrosion and abrasive wear. Together with the Department of Corrosion of the G.V. Karpenko Physical-Mechanical Institute of the NAS of Ukraine (Lvov) the investigations on influence of the chemical composition of the deposited metal on the development of the corrosion process were carried out [19, 20]. The cause of the corrosion is the formation of chromium carbides $Cr_{23}C_6$ along the grain boundaries of metal in the HAZ. The additional alloying of deposited metal provided producing metal with the structure of martensite-aging steel, where during welding and heat treatment the intermetallics are formed resulting in the further hardening of metal and a significant reduction in the probability of formation of chromium carbides $Cr_{23}C_6$ along the grain boundaries (Figure 6).

According to the results of investigations the alloying system Fe–C–Mn–Si–Cr–Ni–Mo–V was

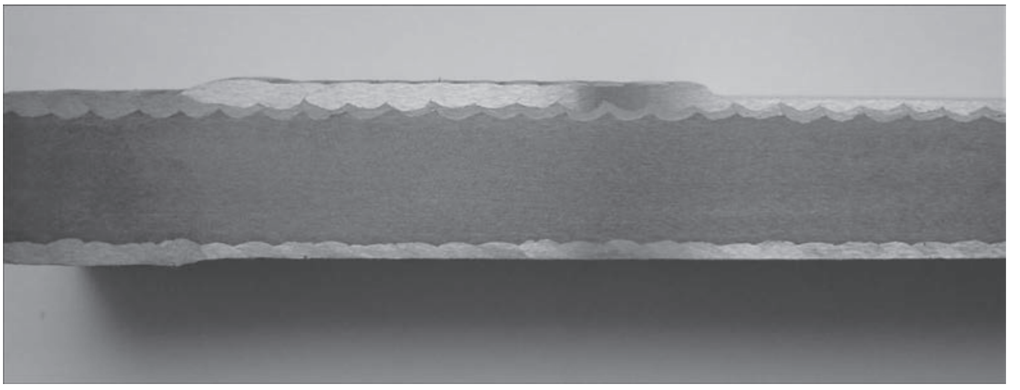

**Figure 7.** Macrosection of plunger fragment after surfacing

optimized using flux-cored wires Veltek-N425, Veltek-N425.01 and Veltek-N425.02 differing by corrosion resistance of deposited metal in the underground waters of different aggressiveness.

Together with the specialists of the plant «NPP Spetsuglemash» (Gorlovka) the technology of two-layer surfacing was developed using wire Veltek-N425 of 2.0 mm diameter under flux AN-26p (Figure 7). The thickness of the deposited layer is 3.0–3.5 mm considering the allowance for machining of 1.5 mm. In the period of 2005–2010 together with the specialists of «Spetsuglemash» performed the works on surfacing of rods and plungers of the stands of domestic and foreign production like M88, MT, 1KD80, 3KD90, 3KD90T, 1M103, DM «Glinnik», «Fazos», the assemblies of sections of the power support MVPO as well as the works on manufacture of new power supports KGUM, 1M103, KTS, sections OPK, supports SPG4000, SSh2.00.000 were successfully carried out. Depending on the volume of orders the consumption of surfacing flux-cored wire was in the ranges of 7–12 t per month.

In the shop conditions the repair surfacing of parts of critical equipment was successfully applied using flux-cored wire. Due to increase in wear resistance of working surfaces the increase in service life of equipment and the cost savings on repair and maintenance were achieved.


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