NEW ELECTRODES FOR REPAIR SURFACING OF RAILWAY FROGS*

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Analysis of technical characteristics of TsNIIN-4 electrodes used for repair of railway frogs showed a necessity in modernization of indicated electrodes and development of new sparsely-alloyed electrodes of similar designation on a basis of low-carbon wire Sv-08. The results of work on selection of optimum composition for gas-slag-forming system of coating and system for alloying of deposited metal as well as technical characteristics of modified electrodes TsNIIN-4M and new sparsely-alloyed electrodes ANN-10 are represented. Technical and economical advantages of new electrodes in comparison with TsNIIN-4 electrodes are shown. Specifications for TsNIIN-4M and ANN-10 grade electrodes were developed, agreed and registered in the «Ukrmetrteststandart» and technological process of their industrial production was created. Results of work on production of pilot-industrial batches of new electrodes and their testing are stated. Development of modern ANN-10 and TsNIIN-4M electrodes allows refusing from application of expensive high-alloy wire Sv-10Kh14G14N4T that reduces a prime cost of the electrodes and increases their competitiveness in the market of welding consumables. 6 Tables, 1 Figure.

Keywords: *electrodes, arc surfacing, railway frog, hardness of deposited metal*

TsNIIN-4 electrodes are the most widespread electrodes for manual arc surfacing of railway frogs, rails and points in Ukraine and CIS countries. The electrode cores from high-alloy wire of Sv-10Kh14G14N4T grade are used for their manufacture. Price of the latter is sufficiently high and makes 8–9 USD per kilogram for Ukrainian consumers considering transport expenses and customs duties. The cores from Sv-10Kh14G14N4T wire have a tendency to buckling (bend out) in a process of heat treatment that increases reject of electrodes on geometry. High price of materials (electrode wire, manganese and metallic chromium) included in the coating increases price of the electrodes even greater up to 12–13 thou USD per ton.

High-alloy wire has higher electric resistance than wire from low-carbon steel. Therefore, current used for surfacing by TsNIIN-4 electrodes is limited in order to prevent electrode overheating, that, in turn, reduces surfacing efficiency.

Surfacing by TsNIIN-4 electrodes can be performed only at reversed polarity direct current, and this fact in some cases results in magnetic blow and formation of defects caused by it.

Aim of the present work lies in development of electrodes based on domestic welding wire Sv-08A and refuse from application of Sv-10Kh14G14N4T wire. Investigations on selection of optimum thickness of electrode coating and content of alloying additives in it were carried out for providing necessary chemical composition of deposited metal in changing of Sv-10Kh14G14N4T wire on Sv-08A wire.

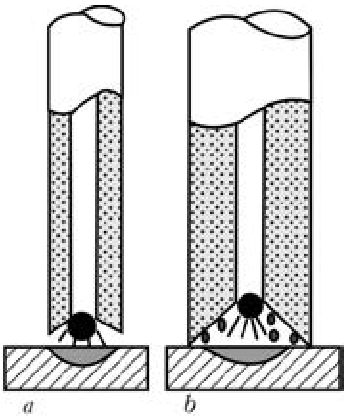
Adjustment of gas-slag-forming part of the coating was carried out for improvement of welding-and-technological properties of the electrodes. Considering high content of metallic powders (65 wt.%) which are «thinning» materials impairing plasticity of an electrode compound in the coating, organic and mineral plasticizing agents were additionally introduced in the coating composition. This insured improvement of the electrode compound plasticity and provided possibility of quality deposition of electrode compound over the core, small polythickness of the coating and good marketable state of the electrodes. Thus, composition of coating of modified electrodes TsNIIN-4M was formed.

Testing of welding-and-technological properties of the modified electrodes showed that they provide stable arcing at direct as well as alternating current. At that, if TsNIIN-4 electrodes

*The paper is prepared on results of execution of Purpose Complex Program of the NAS of Ukraine «Problems of Resource and Safety Operation of Structures, Constructions and Machines» (2010–2012).

Table 1. Welding-and-technological properties of 4.0 mm diameter electrodes

Parameter	TsNIIN-4	TsNIIN-4M
Maximum allowable current, A	140	210
Nominal arc voltage, V	28	25
Possibility of AC surfacing	Only DCRP	DC, AC
Coating diameter, mm	6.0	8.2
Coefficient of coating weight, %	50	135
Linear speed of melting at maximum current, cm/min	24.1	20.3
Efficiency of surfacing, kg/h	1.5	1.8



Type of melting and transfer of metal of TsNIIN-4 (*a*) and TsNIIN-4M (*b*) electrodes

are overheated in welding at current above 140 A, then TsNIIN-4M electrodes allow performing welding at 210 A without significant overheating of the coating. Such an advantage is caused by significantly larger thickness of the coating and application of core from low-carbon wire which has smaller electric resistance in comparison with Sv-10Kh14G14N4T wire.

It should be noted that surfacing using TsNIIN-4 electrodes is to be performed by free arc in order to prevent «bridging» of inter-arc gap by large drop and sticking of electrode to the part. TsNIIN-4M electrodes allow performing touch surfacing, that significantly reduces loading on welder's arm. Thick coating in melting forms a deep crater which is touched by the electrode, that provides such a possibility of surfacing. Large depth of the crater eliminates the possibility of bridging of arc gap by drop.

Formation of fine-ripple uniform bead, easy separability of slag crust and insignificant metal spattering are provided in surfacing by modified TsNIIN-4M electrodes as experiments showed. Table 1 shows the main indices of welding-and-technological properties of the electrodes. Linear speed of melting of TsNIIN-4M electrodes is lower than that of TsNIIN-4 electrodes, as can be seen from the Table data. Larger thickness of coating of the modified electrodes explains this fact. However, efficiency of surfacing at that is 20 % higher than for TsNIIN-4 electrode that is caused by high content of metallic powders in the coating of the modified electrodes and large thickness of the coating.

Hygiene indices of the electrodes were evaluated on intensity and specific emissions of solid constituent of welding fume (SCWF) (Table 2) and its chemical composition (Table 3).

As can be seen from data presented, specific emissions of SCWF is 15 % lower per 1 kg of molten electrodes and 8–10 % lower per 1 kg of deposited metal in surfacing by TsNIIN-4M than by TsNIIN-4 electrodes.

In our opinion, lower specific emissions of SCWF in welding by TsNIIN-4M electrodes are caused by peculiarities of melting and transfer of electrode metal. As earlier performed investigations showed, the increase of thickness of electrode coating and rise of content of metallic fraction (ferroalloys and metallic powders) in it promote increase of quantity of metal and slag drops coming in a pool from periphery of the electrode (Figure). These drops of metal and slag are not overheated to such high temperatures as a main drop formed on a tip of the electrode core. Therefore, processes of evaporation from the surface of periphery drops are less intensive.

Six-layer depositions were performed using reversed polarity direct current for determination

Table 2. Intensity and specific emissions of SCWF in surfacing by TsNIIN-4 and TsNIIN-4M electrodes (DCRP)

Electrode grade	Mode of surfacing		SCWF emission, g		
	I_w, A	U_a, V	Per 1 min	Per 1 kg of molten electrodes	Per 1 kg of deposited metal
TsNIIN-4	140	26–28	1.26–1.41 / 1.33·3	37.9–43.5 / 40.6·3	52.8–55.2 / 54.3·3
TsNIIN-4M	200	24–25	1.46–1.53 / 1.50·3	33.9–35.0 / 34.5·3	49.3–51.7 / 50.7·3

Note. Here and in Table 6 the maximum and minimum values are given in numerator, and average values of indices and number of experiments — in denominator.

Table 3. Chemical composition and hardness of metal deposited by TsNIIN-4 and TsNIIN-4M electrodes

Electrode grade	Weight fraction of elements, %							Hardness *HRC*
	C	Si	Mn	Cr	Ni	S	P	
TsNIIN-4	0.80	0.62	13	22.40	2.90	0.035	0.037	29
TsNIIN-4M	0.79	0.45	12.50	23.30	3.20	0.035	0.025	27
Requirements of normative documents	0.50–0.80	0.80	11–14	22–28.50	2–3.50	0.035	0.040	25–37

Table 4. Results of calculation of costs of materials for manufacture of 1 t of electrodes

Used materials	TsNIIN-4		TsNIIN-4M	
	Consumption per 1 t of electrodes, kg	Cost, UAH	Consumption per 1 t of electrodes, kg	Cost, UAH
Gas-slag-forming	176	747	154.7	712
Alloying	124.5	16,340	340.0	38,614
Plasticizing and binding agents	75	390	164.5	877
Welding wire Sv-10Kh14G14N4T	678	61,427	–	–
Welding wire Sv-08A	–	–	467.0	3526
Total	–	78,904	–	43,729

of chemical composition and hardness of metal deposited by TsNIIN-4 and TsNIIN-4M electrodes. Value of current made 140 and 200 A for TsNIIN-4 and TsNIIN-4M electrodes, respectively. Spectral method was used for analysis of chemical composition of the deposited metal. Data from Table 3 shows that modified TsNIIN-4M electrodes completely meet the requirements of normative documents for TsNIIN-4 electrodes on chemical composition and hardness of deposited metal.

Modernizing of TsNIIN-4 electrodes allowed refusing from expensive Sv-10Kh14G14N4T wire. As can be seen from Table 4, expenses on materials for manufacture of modified electrodes are lower (on 35175 UAH) than for TsNIIN-4 electrodes.

High service properties (wear resistance, hardness etc.) of the deposited metal can be provided at more sparsely alloying (less content of chromium, absence of nickel etc.) in comparison with alloying applied for TsNIIN-4 electrodes. Therefore, sparsely-alloyed electrodes ANN-10 of the same designation as TsNIIN-4 were developed at the E.O. Paton Electric Welding Institute in parallel with modernization of TsNIIN-4 electrodes.

ANN-10 electrodes are analogues to foreign electrodes UTC BMC of German company UTP (today «Boehler Schweiβtechnik Deutschland»), which have been already delivered in Ukraine more than ten years. All-Russian Institute of Railway Transport on the results of tests made back in 1996 stated that UTP BMC electrodes significantly exceed TsNIIN-4 electrodes on mechanical and technological properties and can be used in repair of railway frogs. At that, content of chromium and nickel in the metal deposited by them are significantly lower (Table 5).

Testing of pilot batch of ANN-10 electrodes, manufactured at the E.O. Paton Electric Welding Institute, showed that they are comparable with UTP BMC electrodes and exceed TsNIIIN-4 electrodes on welding-and-technological properties.

Sparsely-alloyed electrodes are in order higher than TsNIIN-4 electrodes and 2–3 times than

Table 5. Chemical composition of metal (wt.%) deposited by TsNIIN-4, TsNIIN-4M, UTP BMC and ANN-10 electrodes

Electrode grade	C	Mn	Si	Cr	Ni	S	P
TsNIIN-4	0.5–0.8	11–14	≤0.8	22–28.5	2–3.5	≤0.035	≤0.040
TsNIIN-4M	0.5–0.8	11–14	≤0.8	22–28.5	2–3.5	≤0.035	≤0.040
UTP BMC	0.6	16.5	0.8	13.5	–	0.032	0.036
ANN-10	0.4–0.8	14.5–18.5	0.6–1.0	12–15	–	≤0.040	≤0.040

Table 6. Impact toughness of metal (J/cm^2) deposited by sparsely-alloyed electrodes of pilot batch, TsNIIN-4 and UTP BMC electrodes of 4.0 mm diameter on specimens of type IX

Testing temperature, °C	UTP BMC	TsNIIN-4	Sparsely-alloyed electrodes
20	$\frac{36.3–71.9}{54.2·3}$	$\frac{8.8–16.7}{11.8·3}$	$\frac{111.0–115.5}{113.5·3}$
−20	$\frac{20.9–35.4}{28.5·3}$	$\frac{8.6–10.6}{9.7·3}$	$\frac{92.6–103.8}{97.3·3}$

UTP BMC electrodes on impact toughness of the deposited metal (Table 6).

Indicated effect becomes apparent at normal as well as at lower temperature (−20 °C), that is, obviously, related with more fine-grained austenite structure in comparison with UTP BMC electrodes. According to existing opinion, the metal deposited with TsNIIN-4 electrodes contains extremely high quantity of chromium, that causes low level of their mechanical properties and, first of all, impact toughness.

ANN-10 electrodes are more favorable from economical point of view since their prime cost is lower than of TsNIIN-4 and TsNIIN-4M electrodes due to smaller consumption of expensive ferroalloys and application of low-carbon wire Sv-08A as a core instead of expensive high-alloy wire Sv-10Kh14G14N4T.

TsNIIN-4M and ANN-10 can be ordered in the PWI Scientific-and-Engineer Center on Consumables for Welding and Surfacing.

Conclusions

1. Replacement of cores from high-alloy wire Sv-10Kh14G14N4T by low-carbon wire Sv-08A was used for modernization of composition of TsNIIN-4 electrodes' coating that allows improving technological and hygiene indices of the electrodes and reducing their prime cost by 30–35 %.
2. Sparsely-alloyed ANN-10 electrodes exceeding TsNIIN-4 electrodes on technological characteristics were developed for surfacing of railway frogs and points.
3. ANN-10 electrodes are more favorable than TsNIIN-4 from economical point of view since they have the minimum prime cost due to lower consumption of expensive ferroalloys and application of low-carbon wire Sv-08A as a core.
4. Packages of normative documents were developed for TsNIIN-4M and ANN-10 electrodes that allows starting their industrial production.

Received 24.01.2013

NEWS

Diagnostics of Stressed State of Structures and Constructions Based on the Method of Electron Speckle-Interferometry

Residual stresses are known to be the cause for many accidents occurring in operation of facilities. Such accidents involve considerable expenses for repair and reconditioning of the equipment, as well as potential hazard for human life and health.

The proposed technology improves the reliability and life of structures and constructions made from various structural materials. Instrumentation for on-line diagnostics of the stressed state and computer system of processing and analysis of the data obtained by the method of electron speckle-interferometry, operate in real time mode. The instrumentation is compact and allows determination of residual stresses under the actual service conditions for assessment of operational reliability of structures and constructions.

Equipment components: compact small-sized (17 mW) source of coherent laser radiation, polarized light guide designed for laser radiation transmission into the controlled zone;

- controlled piezooptic element designed for achieving a phase shift in processing of optical data;
- speckle-interferometer designed for strain measurement at stress relaxation in the controlled zone;
- highly-sensitive CCD-camera designed for transmission of reflected laser radiation to computer memory;
- computer designed for entering, processing and analysis of optical data derived at strain measurement in the controlled section of the structure;
- spare part kit.