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ELECTRIC ARC WELDING AND SURFACING IN REPAIR OF RAILS OF KYIV UNDERGROUND

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Operation of underground lines has own peculiarities. The most critical element of track is the rails, in which joints are particularly stressed place. Decrease of number of bolted joints significantly reduces the probability of defect formation in the rails. Experience of the E.O. Paton Electric Welding Institute on application in Kyiv underground of a new method of rails joining, namely automatic consumable electrode electric arc bath welding, is presented. It provides high productivity of welding in comparison with alumothermal welding and required mechanical properties of the joints. Restoration of surface of the rails and parts of crossing pieces is recommend to be performed using semi-automatic arc surfacing with self-shielded flux-cored wire. 4 Ref., 1 Table, 3 Figures.

Keywords: *arc bath welding, arc surfacing, rail joints, restoration of rail surface*

In modern Kyiv transport infrastructure the underground is the most reliable type of transport capable to transport the maximum number of passengers per unit of time. It covers more than 50 % of total volume of city passenger operations. Today Kyiv underground takes 24th place in the world on traffic flow, at that being only 49th on line length. Up to 2017 the Kyiv underground has three acting lines, the total operation length of which is 69.65 km with 52 stations and average daily passenger operations exceed 1.3 mln of people [1].

Kyiv underground is a multiline enterprise, modern engineering complex. 11 maintenance services, 3 electrodepots (TCh-1 «Darnitsa», TCh-2 «Obolon» and TCh-3 «Kharkovskoe»), car-repair plant (CRP), board of directors on underground construction act as its constituents.

Arrangement of track, conditions of its operation and peculiarities of interaction of track and rolling rock on underground lines significantly differ from the same on main railway transport.

Railway track in the Kyiv underground is mainly located in the tunnels with small extension of the main tracks on the surface (around 9 %). Length of spans between the stations makes from 1.0 to 2.5–3.0 km that is far less in comparison with main railways, where length of the spans usually makes from 6.0 to 10–15 km and more. Such a density of station location is caused by the need of development of traffic flows under conditions of dense urban development.

Operation conditions on the underground lines are sufficiently intensive, i.e. at relatively small axial loads on rails (static load P_s = 150 kN, dynamic P_d = = 172 kN) the average traffic density approaches and, in some cases, exceeds the average traffic density of the main railways (for example, in Kyiv underground the average traffic density reaches D_{av} = 25.23 mln of ton-kilometer/km gross per year, when on the main lines of «Ukrzaliznytsya» (UZ) this index makes 17–17.8 mln ton-kilometer/km gross per year, and on the main tracks of main lines of UZ it is 35–45 mln ton-kilometer/km gross per year). At that, intensity of trains traffic in the underground during «rush-hours» reaches 40 pairs of trains per hour, and on average 352 pairs of trains per day, which significantly exceeds this index for tracks of the main railways. Train speeds reach 70–80 km/h that is close to speed of freight and suburban trains on the mainline transport.

The rails are the main and the most critical element of a track structure. The rails are designed for guiding the wheels of rolling stock, directly accept, distribute and transfer load from the wheels to a rail seat.

Places of joining of rails between each other are called joints. By structure there are temperature, insulating and welded joints.

The gaps in the temperature joints between the rails, connected by bars, are left for having a possibility to change of a rail length at temperature variation. There is a fracture of elastic rail line and additional impact-dynamic effect of wheels on the track as a result of break of integrity and change of bending stiff-

Figure 1. Set of pilot equipment for automatic arc surfacing of rails with flux-cored wire

ness of trackway in the bolted joints during passing of the rolling stock wheels. Therefore, the joint is the most stressed place of the track. Around 35–50 % of labor expenses on track maintenance are related with joints presence. Besides, significant part of all rail defects, which appear in process of their operation, propagates mainly in a joint region. Respectively, decrease of amount of bolted joints by their replacement for welded ones as a result considerably reduces intensity of defect formation in the rails in the process of their operation.

E.O. Paton Electric Welding Institute of the NAS of Ukraine has proposed a new method of rail welding, i.e. automatic consumable electrode electric arc bath welding for replacement of bolted joints [2]. This method provides higher properties of welded joints than traditional manual arc and alumothermal welding, and has already found application in welding of tram and crane tracks [3].

Since a rail surface in the joint region is subjected to higher wear than the whole working surface of rails, which significantly longer preserves its service properties, restoration surfacing of separate areas of rail track elements is cheaper than replacement of them by new elements.

Figure 2. Automatic consumable electrode electric arc bath welding in the tunnel of Kyiv underground

Repair of rails is one the most economic methods of their service life extension. It is carried out in the process of operation without their removal from the track as well as with removal at different operations, at that first variant is more preferable from economy point of view.

The most popular and universal method of repair and restoration of rail worn surfaces and parts of crossing pieces is surfacing. Railway surfacing is widely used as a mean for extension of service life of rails and other metallic elements of the track structure [4]. Traditionally, manual electric arc welding with coated electrodes has been used for these purposes for long years. This method is successfully enough used in the cases where the volumes of repair works are relatively small, and, in the places, where access to repair zone is complicated. In the same place, where the volumes are impressive, a semi-automatic electric arc surfacing using self-shielded flux-cored wire is used.

The specialists of the E.O. Paton Electric Welding Institute of the NAS of Ukraine and line, tunnel construction and building service of CE «Kiev metro» proposed to use automatic electric arc surfacing with self-shielded flux-cored wire for repair of underground rails. It has a series of advantages in comparison with manual electric arc surfacing with stick electrodes and semi-automatic surfacing, namely high labor efficiency, culture of production and quality of surfacing operations. Since the process is continuous, number of the defects in the deposited metal and near-weld zone is reduced to the minimum, consumption of welding consumables is cut down dramatically, time for mechanical treatment of area restored by surfacing is decreased and no preheating is necessary, that shortens total time of repair.

During 2013–2015 members of the E.O. Paton Electric Welding Institute together with line, tunnel construction and building service of CE «Kiev metro» carried the investigations and experimental works in scope of complex program of the NAS of Ukraine «Problems of life and safety of service of structures, constructions and machines». The aim of these works was development of surfacing technology for rail defect repair and elimination of temperature bolted joints using automatic arc welding under conditions of acting underground tracks. A pilot equipment (Figures 1, 2) different by high mobility, necessary for performance of active repair operations, including under tunnel conditions, was developed and manufactured.

Based on agreed specifications a necessary technical documentation was developed, namely Technical regulations «Performance of pilot works on recon-

Results of three-point bending tests of reference specimens of rail joints

Zone of tension of full-scale specimens on 1 m span	Fracture loading for rails of type, kN		Bending deflection, mm
	R50	R65	
Base (loading on head) Head (loading on base)	–	1650 1380	–
Base (loading on head) Head (loading on base)	1160 860	–	22 15

struction of track elements using electric arc surfacing with flux-cored wire on Kyiv underground tracks» and «Performance of pilot works on elimination of temperature joints of rails using automatic consumable electrode electric arc bath welding on Kyiv underground tracks». Also the reference specimens of rails R50 and R65 were welded under laboratory conditions. The rails were provided by Kyiv underground. They passed three-point transverse bending tests at Kyiv rail welding enterprise of the track service of South-West railway. The results of tests (Table) corresponded to the Regulation requirements.

In November–December 2016 five joints of R50 rails and ten joints of R65 rails were welded on underground sections of all three lines of Kyiv underground, and in 2017 repair of 9 defects in form of chipping and delaminations of metal in the joints (code of defect 17.1 on TsP/0061 «Classification and catalogue of defects and damages of rails in Ukrainian railways») was performed on the underground and open sections. Indicated type of defect (Figure 3) is one of the most widespread (around 16 % from total number of rail defects on acting tracks of Kyiv underground).

Now the welded joints and repaired rails are in pilot operation and pass regular visual and ultrasonic control. The results of operation will be considered

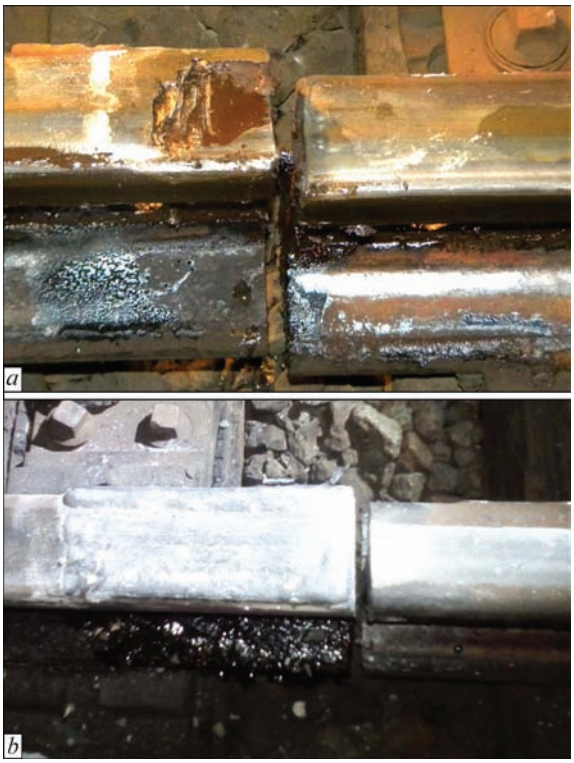

Figure 3. Rail defect 17.1 (*a*) and appearance of rail after surfacing (*b*)

in development of the documentation necessary for further commercial implementation of indicated technologies in repair of Kyiv underground tracks.

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