NEW TECHNOLOGY FOR REPAIR OF GUIDE SURFACES OF AXLE BOX OPENING OF SIDE FRAME OF THE 18-100 MODEL FREIGHT CAR TRUCK

G.V. KUZMENKO[1], **V.G. KUZMENKO**[1], **V.I. GALINICH**[1], **V.I. LIPISY**[2] and **V.V. NESTYKAJLO**[2]
[1]E.O. Paton Electric Welding Institute, NASU, Kiev, Ukraine
[2]Rolling Stock Design and Technology Bureau of «Ukrzaliznytsya», Kiev, Ukraine

The electric arc hardfacing technology based on application of embedded electrodes with wire feed channels is described. The technology provides the specified thickness of the deposited layer. The quality of formation corresponds to the quality of the cast metal surface and requires no machining. Welding consumables (flat electrode and flux-cored wire) as well as special equipment were developed.

Keywords: *electric arc hardfacing, embedded electrode, railway cars, hardfacing equipment, hardfacing consumables, repair of parts, side frame of truck*

The progress in modern engineering is characterized by constant overloading of service conditions of machines and equipment. For such conditions, most parts in machine building are recommended to manufacture with wear-, corrosion- or heat-resistant coatings on their working surfaces. The quality of metal surfaces of parts and units subjected to the heaviest wear can be improved by different methods. Hardfacing is the simplest, most affordable and least expensive method among them. It provides metal saving, improves performance of equipment and machines, reduces their downtimes due to repair, and leads to increase of the efficiency of public works.

Railway transport comprises a large number of parts which intensively wear out during operation. These parts include a wheel–rail pair, surfaces of the devices for coupling of cars, parts and units of car trucks, etc. One of such parts is a side frame of truck of the 18-100 model freight car, which is most common in the territory of the CIS and Baltic countries (Figure 1). The surfaces of axle box opening of this part suffer from an intensive impact-abrasive loading in the process of operation. The side frame is a large-size (measuring 2413 × 654 × 620 mm, and approximately 420 kg in weight) cast structure made from low-alloy steel 20GL or 20GFL. It is the main element of the freight car truck, which transfers load on the axle through axle boxes.

The guide surfaces of the side frame axle box opening (four surfaces 45 × (120–150) mm in size per opening, or eight surfaces of a total area of about 500 cm^2 per frame) are subject to repair, according to the existing norms, to ensure the required width of the axle box opening, in case of their wear to not more than 8 mm per side. These surfaces are clad by the existing technology using mechanized or manual arc hardfacing methods, which fail to provide the required quality of repair and productivity of work. As a result, a large amount of the side frames soon need to be repaired again. In this connection, it is a pressing problem to develop such a technology for repair of guide surfaces of the side frame, which would provide their quality repair and high wear resistance at high deposition efficiency.

It is known that the deposition efficiency can be increased by increasing the welding current. In automatic single-wire hardfacing, the value of the welding current is limited by section of the electrode and reliability of its contact with the current contact jaw. The use of two or more wires reduces this limitation, since the electrode section and contact area with the current contact jaw increase, thus allowing reduction of the welding current. Therefore, automatic multi-

Figure 1. Side frame of four-wheel truck of 18-100 model freight car

electrode hardfacing is more efficient than the single-electrode one. Increase in the number of electrodes also leads to qualitative changes in the process of their melting, which transforms from the continuous into pulse one. This provides decrease in total heat input and deformation, substantial reduction of the base metal penetration depth (by 10–15 %), 25 % decrease in consumption of the electric power per kilogram of the deposited metal, and improvement of quality and performance of the deposited layer [1]. At the same time, multi-electrode hardfacing under forced conditions has an important drawback — satisfactory formation of the deposited metal is possible only in flat position.

The fundamentally new electric arc welding and hardfacing process developed by the E.O. Paton Electric Welding Institute of the NAS of Ukraine in the last several years [2, 3] was used for the development of the technology for repair of side frame guide surfaces. It consists in utilization of the large-section flat electrode with an insulating coating, which is preliminarily introduced into a gap between the parts to be welded (embedded electrode technology). Steel core of the electrode has longitudinal channels, through which solid or flux-cored wires in amounts that depend on width of the electrode are fed in the process of its melting. In hardfacing, one of the parts is replaced by a forming device. Thus, this is a principle of forced formation of the deposited metal, which allows applying this process in positions other than the flat one without significant limitation of hardfacing conditions. Flow diagram of hardfacing with embedded electrode is shown in Figure 2. Its advantage in comparison with the other existing ones is the possibility of performing the process with the electric arc that burns in parallel to the surface treated. This makes it possible to avoid the direct effect of the arc on surface of the base metal and considerably decrease the degree of penetration of the latter. In addition, electric arc hardfacing with embedded electrode allows deposition of fairly large surfaces per pass. The scheme of positioning of the flat electrode in parallel to the deposited surface and utilization of the principle of forced formation permit thickness of the deposited layer to be preset quite accurately within the certain ranges (from 5 to 20 mm) by using corresponding sizes of the embedded electrode and forming device, as well as by regulating the gap between the latter and base metal surface.

The following sequence of operations was used for the development of the technology for repair of side frame guide surfaces:

• if necessary, manual or mechanized hardfacing of the guide surfaces to provide their required width size (nominal — 160^{+1}_{-2} mm);

• machining of worn-out guide surfaces to provide 346 mm width of the axle box opening;

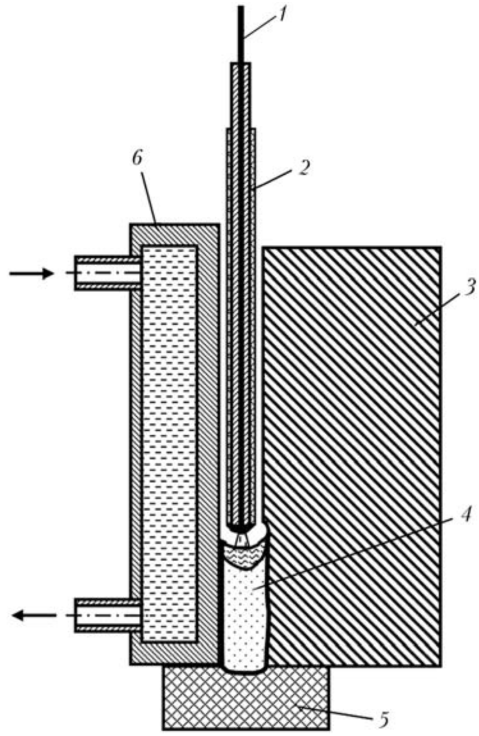

Figure 2. Flow diagram of the process of electric arc hardfacing with embedded electrode: *1* — welding wire; *2* — embedded electrode; *3* — part being clad; *4* — deposited metal layer; *5* — backing; *6* — water-cooled mould

• automatic hardfacing of the guide surfaces to provide 335 mm nominal width of the axle box opening.

With this technology there is no need to apply machining after hardfacing, which leads to increase in hardness of the deposited metal and may significantly extend the overhaul life and limit repair costs.

The specialists of Rolling Stock Design and Technology Bureau of «Ukrzaliznytsya» and E.O. Paton Electric Welding Institute developed the experimental setup (Figure 3) for optimization of the hardfacing equipment and technology, which consists of:

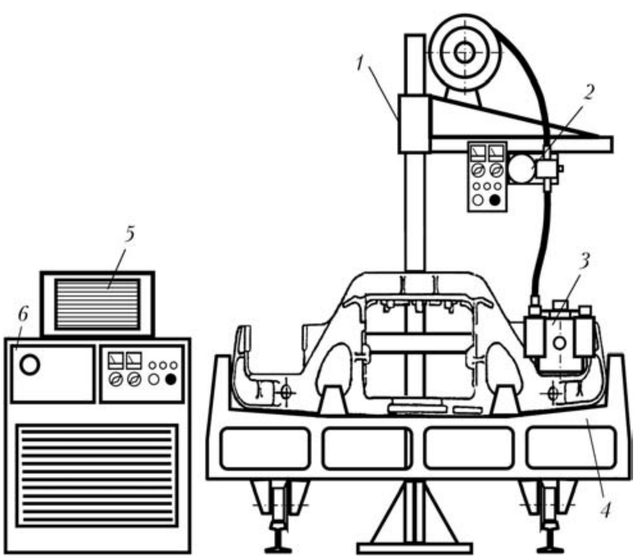

Figure 3. Scheme of experimental setup for hardfacing of side frame guide surfaces of truck of freight car (see designations in the text)

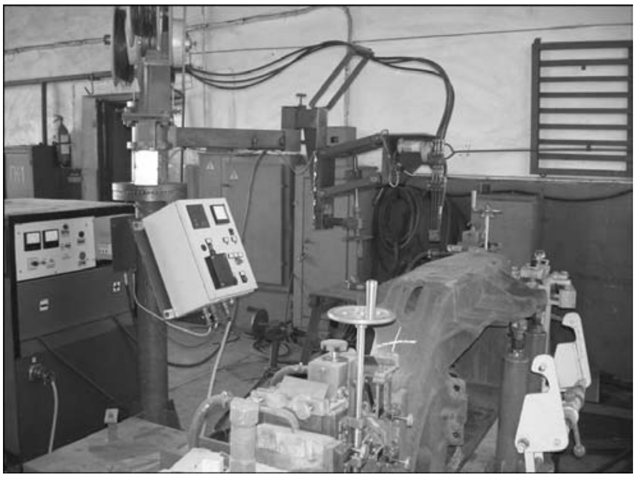

Figure 4. Experimental-industrial setup for hardfacing of guide surfaces of axle box opening of side frame of truck of the 18-100 model freight car

- building berth for positioning and fixing of the side frame during hardfacing in «opening up» position;
- block of chill moulds *3*, providing quality formation of the guide surfaces (the chill moulds are equipped with special devices for fixation of the embedded electrodes and supply of the welding current to them. They are mounted on each block in front of the corresponding surface being deposited, and are electrically insulated from the chill mould);
- automatic welding device *2*, which is intended to feed welding wires to the deposition zone via longitudinal channels in an embedded electrode, and consists of a welding wire feeder to feed three 1.6 mm diameter wires at a feed speed of 30 to 200 m/h, power and control units, fasteners for welding wires reels, flexible channels for feeding the wires, and power and control cables;
- welding current source *6* — thyristor rectifier VDU-1202;
- independent unit for chill moulds cooling *5*.

The automatic welding device is mounted on rotary column *1*, this providing hardfacing of all side frame guide surfaces in turn.

The setup indexed as KT-107 (Figure 4) was manufactured and tested at experimental production of the Rolling Stock Design and Technology Bureau of «Ukrzaliznytsya». Besides, the special machine tool for milling of the guide and bearing surfaces of the side frame before hardfacing was also manufactured there.

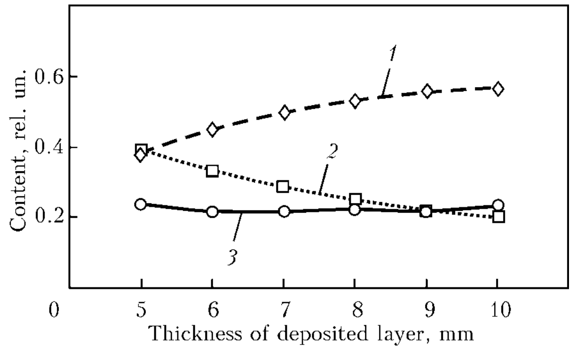

Figure 5. Content of wire (*1*), electrode (*2*) and base metal (*3*) in deposited metal depending on thickness of the deposited layer

The contents of base, electrode and wire metals in the deposited metal for different thicknesses of the deposited layer and optimal process conditions (600 A, 25 V) were calculated from the experimental data, based on the fact that thickness of the deposited layer may change in a wide range (from 5 to 10 mm) depending on the degree of wear of the guide surfaces. As can be seen from Figure 5, whereas the content of the base metal remains almost constant and equal to about 0.21–0.23 with a change in thickness of the deposited layer, similar indicators for the electrode and wire vary within sufficiently wide ranges, i.e. from 0.20 to 0.39 and from 0.38 to 0.57, respectively. Thus, the electrode and wire metals should be close in composition, so that a change in thickness of the deposited layer does not lead to any substantial variations in its chemical composition and hardness. Therefore, alloying of the deposited metal should be carried out simultaneously through the embedded electrode and welding wire and in equal proportions to increase its hardness.

Special flat metal-cored embedded electrode ANPM-40 with a section of 3 × 40 mm and 250 mm length, having a 1 mm thick insulating coating on each side (Figure 6), was developed for hardfacing of the side frame guide surfaces. Thus, the total electrode thickness is 5 mm, which provides the deposition thickness over the entire required range from 5 to 8 mm. The electrode core is made from low-carbon cold-rolled steel of the 08kp (unkilled) grade, while the necessary alloying of the deposited metal is per-

Chemical composition of the materials and their hardness

Object of investigation	Content of element. wt.%						Hardness *HB*
	C	Si	Mn	V	S	P	
Embedded electrode ANPM-40	0.12	0.23	0.78	–	0.018	0.023	–
Wire PP ANPM-4	0.11	0.31	1.43	–	0.014	0.016	–
Metal of side frame (steel 20GL)	0.21	0.27	1.37	–	0.032	0.028	125–131
Metal of side frame No.2 (steel 20 GFL)	0.23	0.33	1.39	0.011	0.035	0.032	154–165
Deposited metal No.1	0.14	0.26	1.26	–	0.021	0.023	135–143
Deposited metal No.2	0.13	0.25	1.32	–	0.019	0.020	139–147

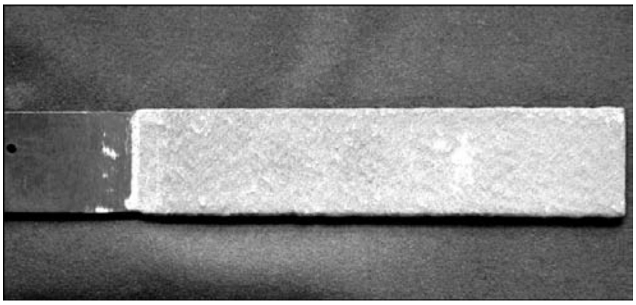

Figure 6. Embedded electrode ANPM-40 for hardfacing of side frame guide surfaces

formed through its coating, the weight factor of which is approximately 35 %. The 1.6 mm diameter flux-cored wire of the PP ANPM-4 grade was also developed to compensate for shortage of the deposited metal and provide its additional alloying.

Samples of the side frames were deposited with the KT-107 setup by using electrodes ANPM-40 and wire PP ANPM-4. At I_w = 650 A and U = 26 V, the time of deposition of each surface is about 1.5 min, which, including the preparation time, allows achieving the efficiency of up to 8 side frames per shift.

Examination of the deposited metal showed that it had no pores, cracks and slag inclusions. Chemical compositions of the base metal of the side frames, embedded electrode, wire, metal of experimental depositions and their hardness are given in the Table. As can be seen from the Table, hardness of the deposited metal is at a level of the corresponding value of the side frame base metal. To increase wear resistance of the side frames, the samples were also deposited by using welding consumables that provide increased hardness of the deposited metal. For that, ferroalloys (ferrochromium, ferromolybdenum, ferrovanadium etc.) were additionally introduced into a composition of the embedded electrode coating and into the charge of the flux-cored wire, which provided hardness of the deposited metal at a level of *HB* 250–300.

Quality of the deposited metal surface corresponded to that of the cast metal and required no subsequent machining. A fragment of the side frame with two deposited surfaces is shown in Figure 7.

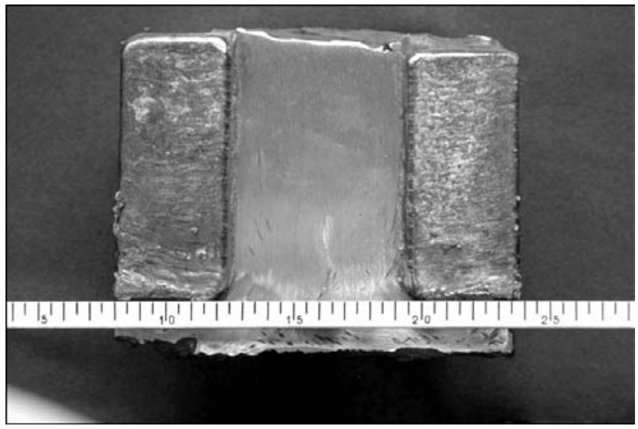

Figure 7. Fragment of side frame with two deposited guide surfaces

CONCLUSIONS

1. The fundamentally new technology for electric arc hardfacing of worn-out surfaces was developed by the E.O. Paton Electric Welding Institute of the NAS of Ukraine. The technology is based on the use of a flat electrode coated by an insulating layer with channels to feed wire, which is preliminarily introduced into the gap of a specific size between the surface to be deposited and a special copper water-cooled forming device (chill mould).

2. Experimental-industrial setup KT-107 was developed and manufactured together with Rolling Stock Design and Technology Bureau of «Ukrzaliznytsya» for hardfacing of side frame guide surfaces of truck of the 18-100 model freight car. The setup is composed of a special welding equipment and building berth for positioning of frames during hardfacing. In addition, the E.O. Paton Electric Welding Institute developed specialized welding consumables, in particular, flat electrode ANPM-40 and flux-cored wire PP ANPM-4.

3. Experimental-industrial repair of worn-out side frames by the new hardfacing technology with embedded electrode was carried out by using a setup located in the territory of Rolling Stock Design and Technology Bureau of «Ukrzaliznytsya». The time necessary for hardfacing of one frame (8 surfaces 45 × × 50 mm in size) is such that it makes it possible to repair up to eight frames per shift.

4. The new hardfacing technology provides preset thickness of a layer of the deposited metal, the quality of its surface corresponding to that of the cast metal, thus requiring no additional machining. Moreover, increased hardness of the deposited metal (*HB* 250–300) can be provided by its additional alloying through the coating of the embedded electrode and charge of the flux-cored wire, which can significantly increase wear resistance of the side frame guide surfaces.

5. The technology and equipment developed for repair of the guide surfaces of axle box opening of truck of the 18-100 model freight car can be recommended for implementation at «Ukrzaliznytsya» car-repair enterprises.

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