



parts. This process of joining the bimetal assembly is recommended for joining over closed, mated or cylindrical surfaces, using the effect of thermal shrinkage and reduction.

1. Ishchenko, A.Ya., Khokhlova, Yu.A., Fedorchuk, V.E. et al. (2010) *Technological features of producing joints of commercial aluminium with AMg5 alloy at activation of surfaces being joined by molten gallium*. Transact. Nikolaev: NUK, 68–74.
2. Avvakumov, E.G. (2009) *Fundamentals of mechanical activation, mechanosynthesis and mechanochemical technologies*: Integration projects. Novosibirsk: Nauka.
3. Khokhlova, Yu.A., Fedorchuk, V.E., Khokhlov M.A. (2011) Peculiarities of intergranular mass transfer of gallium in aluminium alloy during solid phase activation of surfaces being joined. *The Paton Welding J.*, **3**, 13–15.
4. Ishchenko, A.Ya., Khokhlova, Yu.A. (2009) Evaluation of mechanical properties of microstructural constituents of welded joints. *Ibid.*, **1**, 34–37.
5. Khokhlova, Yu.A., Khokhlov, M.A. (2009) Nanoscale effect in diffusion joints with gallium. In: *Abstr. of Int. Conf. on Welding and Related Processes*. Nikolaev: NUK, 111.
6. Likhman, V.I., Shchukin, E.D., Rebinder, P.A. (1962) Physiko-chemical mechanics of metals. In: *Adsorption phenomena in processes of deformation and fracture of metal*. Moscow: AN SSSR.
7. Tikhomirova, O.I., Pikunov, M.V. (1969) Influence of shape and size of second component particles on properties of gallium solders. *Poroshk. Metallurgiya*, **82(12)**, 51–56.
8. Poletaev, G.M., Starostenkov, M.D. (2010) Contributions of different mechanisms of self-diffusion to fcc metals in equilibrium conditions. *Fizika Tv. Tela*, **52**, Issue 6, 1075–1082.
9. www.svarka-lib.com/node/298/print/64.html
10. www.autodela.ru/main/top/test/svar

INFLUENCE OF VIBRATION OF PARTS ON STRUCTURE AND PROPERTIES OF METAL IN SURFACING

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Presented are the investigation results of structure and properties of metal deposited by induction method with superposition of vibrations in a period of melting of a surfacing consumable. It is shown that the superposition of vibrations leads to improvement of wear resistance of the deposited metal due to refinement of its structure.

Keywords: induction surfacing, inductor, specific power, vertical and horizontal vibrations, deposited metal, structure, wear resistance

An induction surfacing using powders from high-carbon chromium alloy PG-S1 (sormite 1) is widely used for manufacture of operating elements of agricultural machines: plough shares, blades of top cutters, chisels of cultivators etc. At that a deposited metal has a coarse-grain structure with inclusions of coarse chromium carbide [1, 2].

A new technology of induction surfacing using vibrations [3–6] was proposed for refinement of structure and improvement of properties of the deposited metal. It lies in the fact that a part is subjected to vertical and horizontal vibration at the moment when a powder charge is in a molten state. At that, direction of oscillation application (Figure 1) as well as their frequency and amplitude have a great importance.

Investigations of structure, microhardness of structural constituents and wear resistance of the metal deposited by induction method with and without vibration superposition were performed for evaluation of the efficiency of developed technology. The flat samples from steel St3, i.e. sample 1 without vibration, 2 and 3 with vertical and horizontal vibrations, correspondingly, were deposited for performance of the investigations by induction method using a charge containing PG-S1 alloy powder. Surfacing was carried out on a high-frequency generator of VChG 6-60/0.44

type at constant specific power W and time of deposition t (Figure 1, *b*). The modes were similar for all three variant of surfacing, i.e. circuit voltage 5.4 kV; anode voltage 10 kV; circuit current of lamp 1.2 A; anode current of lamp 2 A; deposition time 35 s; oscillation amplitude 0.2 mm at 50 Hz frequency.

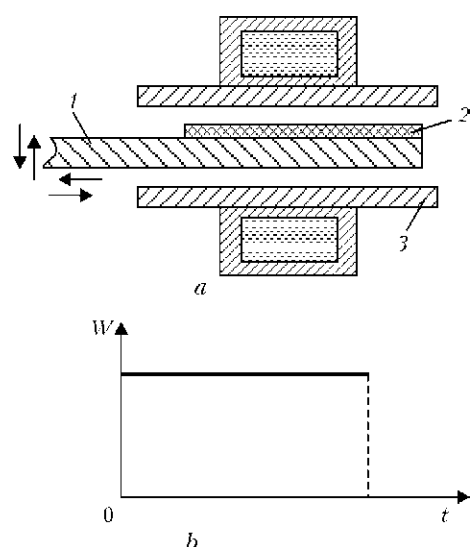


Figure 1. Surfacing scheme (*a*: 1 – part being deposited; 2 – powder-like charge; 3 – inductor; arrows show direction of vibration application – vertical or horizontal), and specific power W of generator in the process of surfacing (*b*)

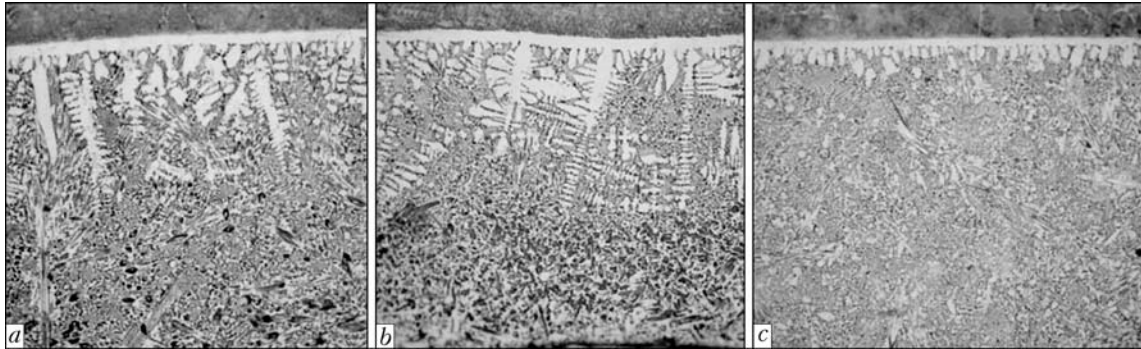


Figure 2. Microstructure ($\times 200$) of the deposited metal of samples 1–3 (a–c)

Samples for investigation of structure and wear resistance of the deposited metal were cut out from the deposited blanks.

Etching of the samples for performance of metallographic investigations was made by stages. Structure of the deposited metal was determined by electroplating technique in 20 % solution of chromic acid (20 V voltage and time of etching 10 s) through a chemical etching in 4 % solution of nitric acid.

Microstructure of the base metal consists of ferrite and pearlite and microstructure of the deposited metal in all investigated samples is made of primary carbides (complex carbides of $(Fe, Cr)_7C_3$ and $(Fe, Cr)_3C$

type) in a form of coarse plates of «pencil» type, having hexagonal cut with well-defined interface to matrix, of carbide eutectics and matrix austenite structure.

The excess carbides, as a rule, are situated in a form of separate plate precipitates in the central part along the width and thickness of the deposited bead. Rectangular and hexagonal precipitates are the carbides of different dispersion. Part of them is the excess plate carbides being sufficiently uniform distributed in the matrix. Microhardness of the carbides varied in the ranges $HV0.5-11710-12830$ MPa.

Common for all variant of the deposited metal is:

- presence in the deposited layer of hypoeutectic zone adjoining to a joining line which is characterized by formation of the dendrites of solid solution (alloyed austenite) with axes of the first and second order, as well as the carbide eutectics crystallized in an interdendritic space. Microhardness of austenite for samples 1 and 2 made $HV0.5-4120-4410$ MPa and that for sample 3 was $HV0.5-4800-5090$ MPa. Besides, a structural inhomogeneity represented by the fact that the hypoeutectic dendrite zone had non-uniform distribution was found along the joining line from the sormite side;

- formation of boundary white strip of the solid solution (alloyed austenite) of variable width 10–20 μm between the deposited and base metals with microhardness $HV0.5-3030-3410$ MPa for sample 1, and $HV0.5-3410-3810$, $HV0.5-3860$ MPa for samples 2 and 3, correspondingly;

- existence of a diffusion zone from the base metal side near the joining line representing itself fine plate pearlite and ferrite along the grain boundaries sometimes with orientation on Widmanstatten structure with microhardness $HV0.5-2440$ MPa appeared as a result of carbon diffusion from the sormite into the base metal.

Microhardness of the structural constituents for three samples is given in the Table.

Differences in the structure of three variants of the deposited metal should be noted. Notable refinement of the carbide constituent is caused by horizontal vibration. The carbides, having hexagonal shape with 10–12 μm mean length of the side, without vibration (Figure 2, a) are refined up to 7–10 μm at vertical

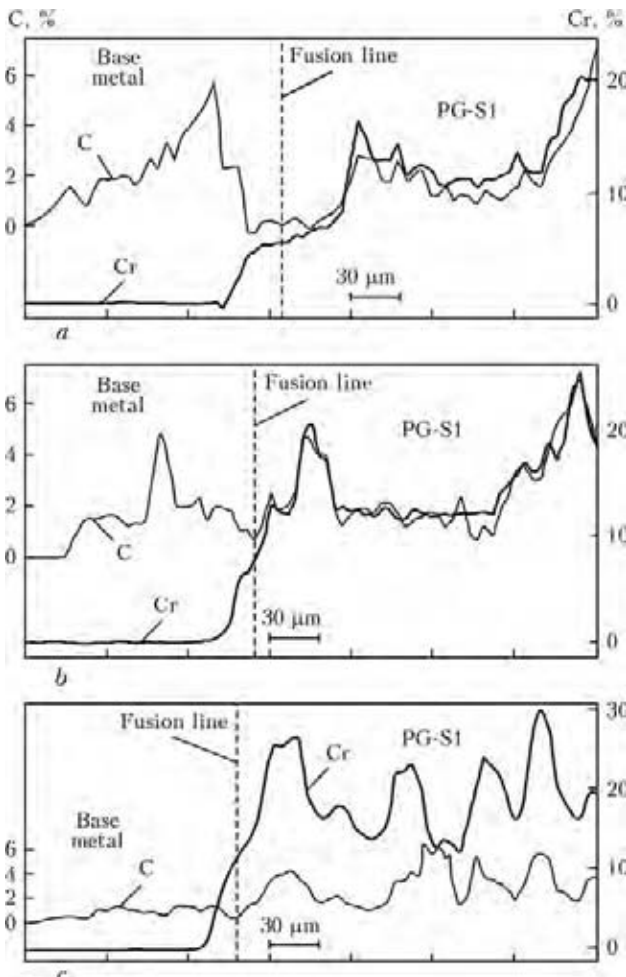


Figure 3. Distribution of carbon and chromium on thickness of the deposited metal in samples 1–3 (a–c)



Microhardness of structural constituents of the deposited metal of PG-S1 type, MPa

Sample No.	Chromium carbide	Matrix	White strip
1	11710-12830	4120-4410	3030-3410
2	11710-12830	4120-4410-4800	3410-3810
3	11710-12830	4800-5090	3860

vibration (Figure 2, *b*) and 3.5–7 μm at horizontal one (Figure 2, *c*).

The maximum depth of the eutectic zone is in samples 1 and 2 (see Figure 2, *a*, *b*) and in sample 3 (Figure 2, *c*) – the minimum one. Zone of austenite dendrites takes the smallest percent along the length of deposit in sample 3 in comparison with samples 1 and 2. The joining line from sormite side at horizontal vibration mainly represents itself the white strip with formation of almost equiaxial austenite grains (see Figure 2, *c*).

Micro X-ray spectrum analysis on the Cameca microanalyzer CAMEBAX SX-50 (Figure 3) was carried out for investigation of distribution of the elements (chromium, carbon) at transfer from the base metal to the deposited one. The analysis for all cases was performed approximately in a center of the deposited layer normal to fusion line at depth up to 350 μm from the fusion boundaries. It is determined that carbon is bounded in the carbides of $(Fe, Cr)_7C_3$ and $(Fe, Cr)_3C$ type in metal of the investigated samples and notable redistribution of carbon near the fusion line was not observed.

Measurements of hardness of the deposited metal on the LECO hardness meter at 0.5 and 3 N loading (Figure 4) showed that sample 3 has the highest hardness. Laboratory tests on wear resistance of the deposited metal of samples 1–3 on machine NK-M [7] were also performed. Test conditions were the following: abrasive – quartz sand with particle size 0.2–0.4 mm; friction path 415 m; pressure 0.466 MPa;

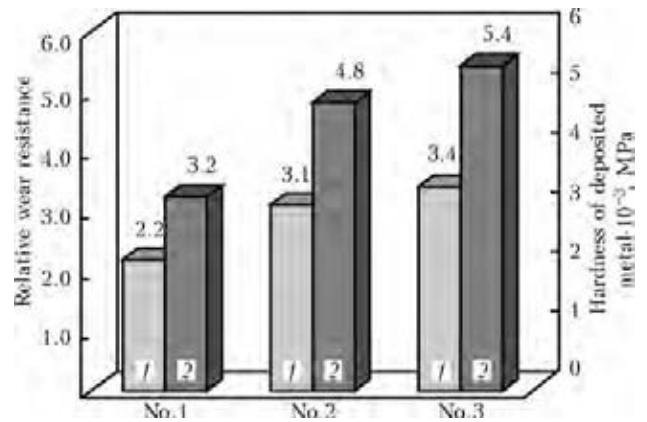


Figure 4. Relative wear resistance (1) and hardness of the deposited metal (2) of samples 1–3

standard sample – annealed steel 45. Figure 4 shows that sample 1 has the lowest wear resistance (2.2) and samples 2 and 3 – the highest (3.1 and 3.4, respectively). Surfacing on scheme accepted for sample 3 provides the highest wear resistance that is explained by favorable structure of the deposited metal and formation mainly of $(Fe, Cr)_7C_3$ carbides and certified by the results of micro X-ray spectrum analysis.

1. Tkachev, V.N., Fishtejn, B.M., Kazintsev, N.V. et al. (1970) *Induction surfacing of hard alloys*. Moscow: Mashinostroenie.
2. Pulka, Ch.V. (2003) Hardfacing the working components of tillage and harvesting agricultural machinery (Review). *The Paton Welding J.*, 8, 35–40.
3. Shably, O.M., Pulka, Ch.V., Senchishin, V.S. et al. *Method for surfacing of thin plane steel parts*. Pat. on useful model 54204 UA. Int. Cl. B23K 13/00. Publ. 25.10.2010.
4. Pulka, Ch.V., Senchishin, V.S. *Device for surfacing of thin shaped disks*. Pat. on useful model 59994 UA. Int. Cl. B23K 13/00. Publ. 10.06.2011.
5. Pulka, Ch.V., Senchishin, V.S. *Method of surfacing of parts*. Pat. on useful model 64371 UA. Int. Cl. B23K 13/00. Publ. 10.11.2011.
6. Shably, O.M., Pulka, Ch.V., Senchishin, V.S. (2011) Vibroinduction surfacing of thin plane parts. In: *Abstr. of 10th Int. Symp. of Ukr. Mechanical Engineers* (Lviv, 25–27 May, 2011), 289–290.
7. Yuzvenko, Yu.A., Gavrish, V.A., Marienko, V.A. (1979) Laboratory machines for assessment of wear resistance of deposited metal. In: *Theoretical and technological principles of surfacing. Properties and tests of deposited metal*. Kiev: PWI.