WEAR RESISTANCE OF DEPOSITED METAL OF THE TYPE OF CARBON AND CHROMIUM-MANGANESE STEELS UNDER THE CONDITIONS OF DRY SLIDING FRICTION OF METAL OVER METAL

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Parts subjected to intensive wear are made from medium- and high-carbon unalloyed or low-alloyed structural steels. Increased carbon content ensures a high hardness and strength of materials. Because of low-alloying, however, their wear resistance is on a relatively low level. High carbon content considerably complicates the technology of reconditioning the above parts, because of the risk of cold cracking in arc surfacing. To recondition this type of parts it is rational to apply consumables producing deposited metal with the structure of metastable austenite. Such a structure can be produced at application of consumables alloyed by chromium and manganese for surfacing. Preliminary work hardening or work hardening directly during service leads to decomposition of metastable austenite and increase of hardness and wear resistance of the deposited metal. The objective of the work was investigation of wear resistance of deposited metal of chromium-manganese class under the conditions of dry sliding friction of metal over metal. Wear resistance of deposited metal of various alloying systems was studied. It is shown that the correlation between hardness and wear resistance is manifested not in all the cases, both for carbon and for austenitic materials. It is found that materials with the structure of metastable austenite are superior to carbon steels as to wear resistance and are preferable at reconditioning of parts from structural medium- and high-carbon steels. 6 Ref., 1 Table, 3 Figures.

Keywords: *arc surfacing, surfacing consumables, sliding friction, wear resistance, structure, hardness*

A considerable number of parts of machines and mechanisms, used in various industries, wears as a result of dry friction of metal over metal. Many of them are reconditioned by various surfacing processes [1–4].

Such parts are usually made from medium- and high-carbon unalloyed or low-alloyed structural steels. Increased carbon content ensures high hardness and strength of materials. However, because of low alloying their wear resistance is on a relatively low level. In addition, at more than 0.5 % C, technology of reconditioning the parts from above-mentioned steels by surfacing becomes much more complicated that is related to formation of quenching structures and cold cracking in the HAZ metal.

Cracking can be avoided through application of special technological measures, such as heating of the surfaced part up to 300–400 °C with subsequent delayed cooling after surfacing.

Application of consumables, providing deposited metal with austenitic structure, has a good effect in terms of crack resistance. However, wear resistance of deposited metal of this type under the conditions of dry sliding friction of metal over metal is on a low level, while the price of consumables for this type of surfacing is quite high and their application is not always cost-effective.

For reconditioning parts of this type, it is more rational to apply consumables, which provide deposited metal with the structure of metastable austenite. Such a structure can be obtained at application of surfacing consumables alloyed by chromium and manganese. Preliminary work hardening or in-service hardening lead to decomposition of metastable austenite, as well as increase of hardness and wear resistance of the deposited metal.

The objective of this work is investigation of wear resistance of the deposited metal with different content of chromium and manganese under the conditions of dry sliding friction of metal over metal. Composition of the studied types of deposited metal is given in the Table. Samples of

Composition of deposited metal, wt.%

Deposited metal type	C	Cr	Mn	Ni	Si	Mo	V	Ti	Cu
U7	0.70	–	0.89	–	0.25	–	–	–	–
30Kh5G5	0.27	4.5	5.0	–	0.20	–	–	–	–
10Kh10G10	0.11	11.0	10.0	–	–	–	–	0.8	–
60Kh20G9N2MD	0.62	20.8	9.0	2.0	0.55	0.5	–	–	0.17
20Kh13G6N6MFD	0.22	13.0	5.8	6.0	0.60	1.4	0.4	–	0.90
50G11M	0.50	0.2	11.0	–	0.80	0.3	–	–	–

deposited metal of the type of high-carbon steel U7 were used as a reference. For comparison, deposited metal alloyed practically by manganese alone was studied, alongside chromium-manganese deposited metal of various compositions.

Investigation of wear resistance of deposited metal was performed in friction machine of M-22 type in «shaft–block» configuration. Samples of 20 mm length and 10 mm thickness with a cylindrical slot in the form of a segment of 20 mm radius and 20 mm chord were used.

A disc of 40 mm diameter made from U7 steel with *HB* 300–350 hardness was used as a counterbody.

Testing conditions were as follows: pressure on the sample $p = 0.5 \pm 0.1$ MPa; friction speed $v = 3 \pm 0.25$ m/s; temperature $T = 60 \pm 20$ °C; duration $t = 1$ h.

Samples were weighed on laboratory scales with 0.0001 g error. Wear by weight Δm was determined as difference of values of sample weight before and after testing. Deposited metal hardness was also measured. Investigation results are given in Figure 1.

Deposited metal structure was identified by the results of metallographic analysis (Figure 2). Producing structures of specified type was ensured by selection of chemical composition of surfacing consumables and surfacing heat inputs.

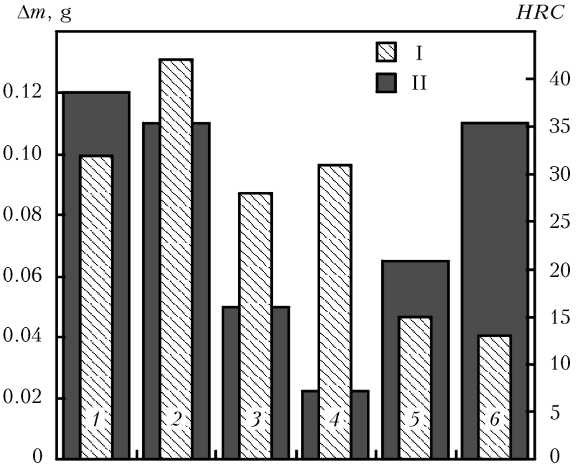

Figure 1. Wear by weight (I) and hardness (II) of deposited metal: *1* — U7; *2* — 30Kh5G5; *3* — 10Kh10G10; *4* — 60Kh20G9N2MD; *5* — 20Kh13G6N6MFD; *6* — 50G11M

Recommendations given in [5] were used in surfacing of austenitic materials.

Testing results showed (see Figure 1) the absence of a direct link between hardness and wear resistance of the studied types of deposited metal.

So, for instance, types of deposited metal U7, 30Kh5G5 and 50G11M have approximately the same wear parameters ($\Delta m = 0.11$–0.12 g), but differ considerably by hardness: 50G11M — *HB* 180; U7 — *HRC* 35; 30Kh5G5 — *HRC* 42. On the other hand, types of deposited metal 20Kh13G6N6MFD and 50G11M have approximately the same hardness — *HB* 150–180, but differ considerably as to wear — $\Delta m = 0.062$ and 0.115 g, respectively.

Deposited metal structure has apparently significant influence on wear resistance. High-alloyed 60Kh20G9N2MD deposited metal with austenitic-martensitic structure had minimum wear (see Figure 2, *d*) and sufficiently high hardness *HRC* 30. Deposited metal 10Kh10G10, as well as 20Kh13G6N6MFD and 50G11M, having metastable austenitic structure (Figure 2, *c*, *e*, *f*), had somewhat inferior wear resistance compared to it. It is obvious that the conditions of wear testing (at relatively small load) did not allow full realization of the possibility of work hardening of these materials. Nonetheless, wear resistance of deposited metal 10Kh10G10 and 20Kh13G6N6MFD is quite high and is much superior to that of hard materials U7 and 30Kh5G5.

From the studied materials having maximum wear resistance (10Kh10G10, 60Kh20G9N2MD, 20Kh13G6N6MFD) preference, in our opinion, should be given to the first of them, not containing any expensive alloying elements, and having sufficiently high wear resistance.

It should be noted that the obtained data are in good agreement with those of [6] as to investigation of wear resistance of steel U7 and deposited metal of ferritic and austenitic classes.

After wear resistance testing, fractograms of friction surfaces of deposited metal samples were studied (see Figure 3), and it was found that in 10Kh10G10 sample with the structure of metastable austenite (Figure 2, *c*) friction surface has uniform relief without any traces of spalling or characteristic furrowed structure (Figure 3, *a*).

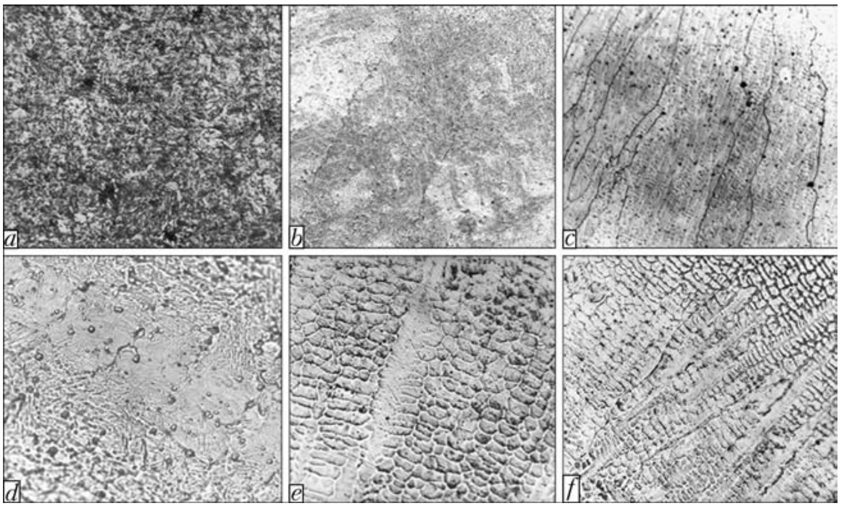

Figure 2. Microstructures (×500) of deposited metal: *a* — U7; *b* — 30Kh5G5; *c* — 10Kh10G10; *d* — 60Kh20G9N2MD; *e* — 20Kh13G6N6MFD; *f* — 50G11M

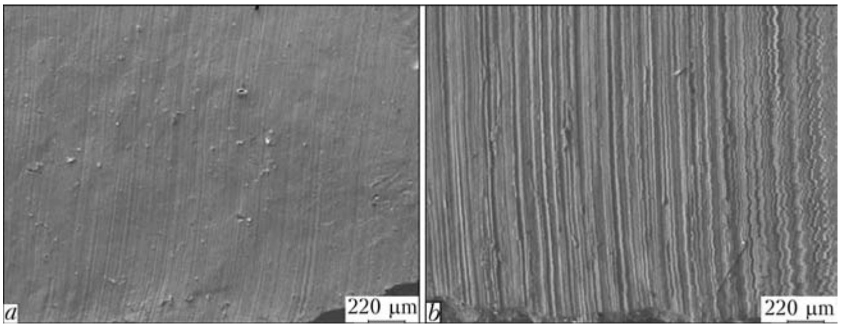

Figure 3. Fractograms of friction surfaces after wearing of deposited metal of the samples: *a* — 10Kh10G10; *b* — 30Kh5G5

In 30Kh5G5 sample with martensitic-sorbitic structure with residual austenite (see Figure 2, *b*), contrarily, the characteristic morphological feature of friction surface is the furrowed structure (Figure 3, *b*), which forms as a result of plastic driving of material from friction surface by wear product particles. Geometrical dimensions of the grooves change in a wide range that is indicative of structural inhomogeneity, and of different wear resistance of structural components of the considered type of deposited metal, respectively.

Conclusions

1. Wear resistance and microstructure of deposited metal of various types was studied. It is shown that the best wear resistance is found in deposited metal with the structure of metastable austenite. Preliminary work hardening or in-service work hardening with increased mechanical loads leads to decomposition of metastable austenite and increase of deposited metal hardness and wear resistance.

2. From the studied types of deposited metal of various alloying systems, deposited metal 10Kh10G10 has an optimum combination of properties.

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