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THE INFLUENCE OF STRAIN HARDENING TO THE STRUCTURE AND PROPERTIES OF FE-C-CR-MN STEELS

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The article deals with problems associated with strain-hardening of Fe-C-Cr-Mn-Ti-Si alloys with low carbon metastable austenite matrix containing 6…7 % (vol.) thermodynamically stable TiC carbide. Objective – research kinetics of strain hardening metastable surfacing alloys system Fe-C-Cr-Mn-Ti-Si. Comparing their workability and durability to the widely used surfacing alloys. Main results of the research: Surfacing chromium-manganese alloy steels with the structure of metastable austenite has high wear resistance to abrasive wear compared to the surfacing of tungsten steel. Durability is largely correlated with the microhardness of the surface layer. With decreasing contents of metastable austenite the hardening effect and durability reduced. For surfacing with martensitic structure a slight strain hardening is measured. This points to the leading role of strain hardening of austenite and phase transformations in wear resistant surfacing alloys. During tests on abrasive wear for chromium-manganese alloy steels wear intensity decreases, but for materials with different structure it is not typical.

Key words: abrasive wear; deformation hardening; the metastable austenite; surfacing; chromium-manganese steel.

Петренко А. М. «Вплив деформаційного зміцнення на структуру та властивості хромомарганцевого наплавленого металу».

Розглянуті питання, пов'язані з деформаційно-фазовим наклепом і зміцненням Fe-C-Cr-Mn-Ti-Si сплавів з маловуглецевою матрицею з метастабільного аустеніту при вмісті 6…7 %. карбідів TiC. Проведені дослідження показали: Наплавлення з хромомарганцевих сталей зі структурою із метастабільного аустеніту мають високу зносостійкість в умовах абразивного зношування у порівнянні з наплавленнями з вольфрамової сталі. Зносостійкість корелює з мікротвердістю поверхневого шару. Із зменшенням долі метастабільного аустеніту ступінь зміцнення і зносостійкість знижуються. Для наплавлень з мартенситною структурою деформаційне зміцнення незначне. Це вказує на ведучу роль деформаційного зміцнення аустеніту та фазових перетворень на зносостійкість наплавлень. При випробуваннях на абразивне зношування для хромомарганцевих сталей інтенсивність зношування зменшується. Для матеріалів з іншою структурою це не характерно.

Ключові слова: абразивне зношування; деформаційне зміцнення; метастабільних аустеніт; наплавлення; хромомарганцева сталь.

Петренко А. Н. «Влияние деформационного упрочнения на структуру и свойства хромомарганцевого наплавленого металла».

Рассмотрены вопросы, связанные с деформационно-фазовым наклепом и упрочнением Fe-C-Cr-Mn-Ti-Si сплавов с малоуглеродистой матрицей метастабильного аустенита при образовании 6…7 % термодинамически стойких карбидов TiC. Проведенные исследования показали: Наплавки с хромомарганцевих сталей со структурой из метастабильного аустенита имеют высокую износостойкость в условиях абразивного изнашивания по сравнению с наплавками из вольфрамовой стали. Износостойкость коррелирует с микротвердостью поверхностного слоя. С уменьшением доли метастабильного аустенита степень упрочнения и износостойкость снижаются. Для наплавок с мартенситной структурой деформационное упрочнение незначительное, что указывает на ведущую роль деформационного упрочнения аустенита и фазовых превращений на износостойкость наплавок. При испытаниях на абразивное изнашивание для хромомарганцевих сталей интенсивность изнашивания уменьшается. Для материалов с другой структурой это не характерно.

Ключевые слова: абразивное изнашивание; деформационное упрочнение; метастабильный аустенит; наплавка; хромомарганцевая сталь.

1. Introduction. Survey of prior research

Increasing durability of machine parts and tools – one of today's actual problems. A promising solution of the problem is obtaining a metastable alloy structure. These structures are capable to “self-organization” under the influence of deformation and wear, allowing them to adapt to the load and obtain high exploitation properties [1-5]. The shortage of material and energy resources causes the necessity of development new materials that contain a limited element concentration that are missing in Ukraine raw base. Composition of surfacing alloys elaborated by the authors [1, 2] has high technological and exploitation properties surfacing, but using molybdenum and vanadium increases the cost of the material. Composition of surfacing alloys elaborated by the authors [1, 2] has a high technological and exploitation properties of surfacing, but using molybdenum and vanadium as stabilizators increases the cost of the material. The lack of a significant amount of stabilizers [3] reduces abrasive wear resistance, also increases the tendency to crystallization cracks forming.

2. Objective – research kinetics of strain hardening metastable surfacing alloys system Fe-C-Cr-Mn-Ti-Si. Comparing their workability and durability to the widely used surfacing alloys.

3. The research basics

3.1 Theoretical feasibility demonstration

The essence of hardening metastable structures is that metastable austenite under the loads undergoes martensitic transformation.

Strain hardening occurs by changing the thin crystal structure. The fragmentation of grains, crushing and splitting blocks of mosaic structures lead to the microstresses rise [3, 4]. The most intensive hardening accompanied by precipitation ultrafine carbides, which are concentrated on grain boundaries and blocks preventing sliding process within them. This increases hardness and durability of surfacing alloys under wear conditions.

Such martensite has some features. It is very dispersed and is placed inside deformation bands. Plates and needles of martensite divide austenite grain. The formation of martensitic phase crystals removes local stress and prevents the embrittlement. Presence of metastable austenite and its decay during plastic deformation enhances durability. Stresses in the complicated strain-state at the "crack tip" will decrease due to volume changes of deformation martensite transformation [1].

Summing up the research results obtained by authors [1-3] we can assume that the effect of metastable austenite strengthening during plastic deformation is determined by the following main factors:

1. by austenite strain hardening;
2. by allocation of dispersed carbide phases;
3. by quantity and distribution martensitic phase formed during deformation;
4. by phase-hardening martensite crystal.

3.2 Methodology of research

Prediction of chemical composition and durability perform mathematical planning methods and artificial neural networks.

Surfacing was performed by cored wire or submerged arc. Weld metal composition and distribution of elements between phases determined by chemical and spectral methods of analysis. The distribution of elements between phases - micro X-ray spectral analysis. As the abrasive medium used abrasive silicon carbide fraction 120…200 microns and granite crumb. To the variant of wearing by abrasive (SiC) the machine of the reciprocating movement of the test sample on the surface of the abrasive opposite body was used. To test the friction on abrasive layer of granite chips or quartz sand - a technique Hauorta.

The extent surface strengthening estimated ratio:

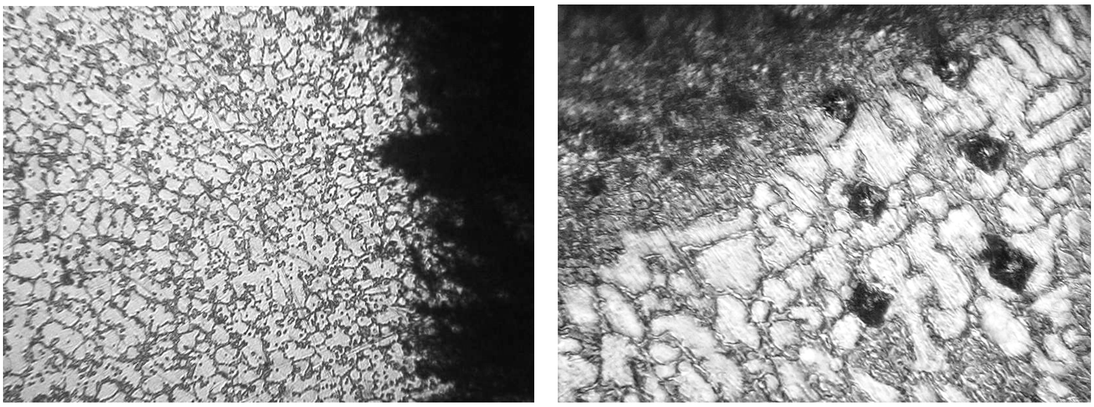
$$H_\mu / H_{\mu 0} = f_1(c, P, v, T, S),$$

were H_μ – microhardness friction surface; $H_{\mu 0}$ – microhardness friction surface before the test; c – chemical and phase composition of surfacing metal; P – nominal and physical pressure; v – speed of relative friction movement; T –temperature; S – friction way.

3.3. Results of the research wear and surface hardening

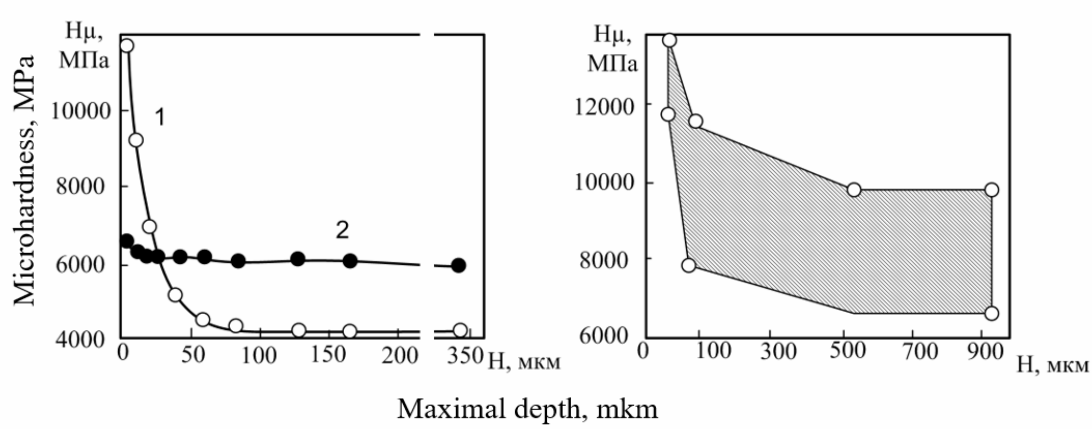
The above (Figure 2, Figure 3) measured data values microhardness growth is most noticeable at the beginning of testing on the way friction about 100-150 m. After passing through the sample of 500 m path friction remains virtually unchanged. Depth of strengthening grows quite rapidly on the path friction up to 500 m. Further changes are less intense and reaches the final value up to 1500-2500 m. Similarly changes and wear intensity (Fig. 4).

The structure near-surface zone of 100Х9Г8Т4С surfacing alloy [6] is austenitic grain, and placed on the grain boundaries titanium carbide and eutectic. Microhardness of austenite grains increases rapidly reaching 9000…10000 MPa. Eutectic microhardness practically unchanged (Fig. 1, Fig. 2).



a. b.

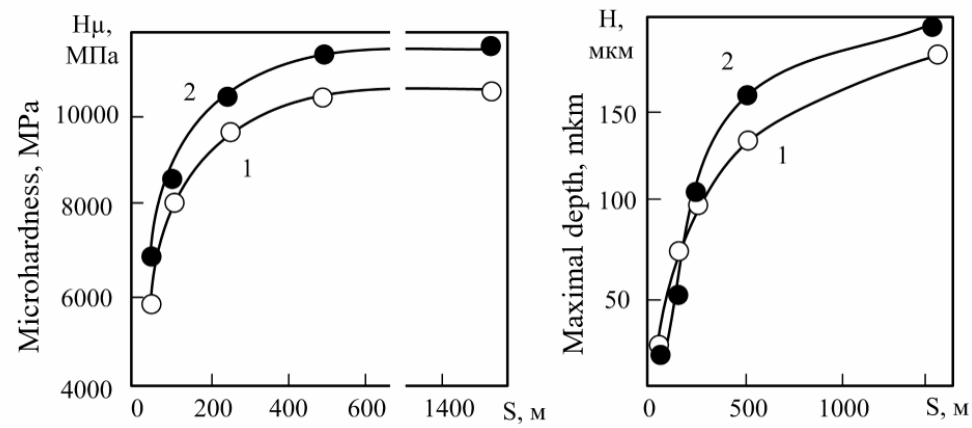
Fig. 1 – Microstructures near-surface zone of friction 100Х9Г8Т4С (exposure time of abrasive wear equal to 50 m (a) and 1500 m (b)), ×200



a. b.

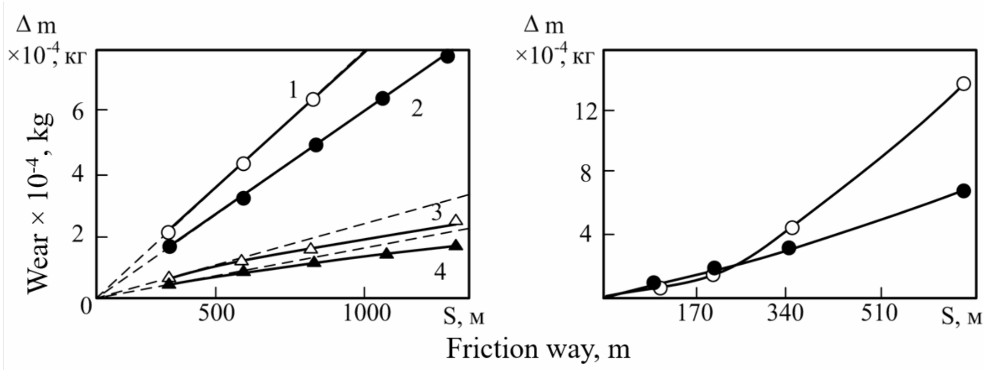
Fig. 2 – Distribution of microhardness in the near surface layer:
a. — 150Х10Г10Т4С abrasive wearing (silicon carbide),
б. — 30В9Х3Ф, opposite conterbody — Р18. *1.* — austenite; *2.* – eutectic

A more long-term effects of wear occurs structures with a high degree of biting and high microhardness (over 10000 MPa).



a. b.

Fig. 3 – Microhardness growth (a) strengthening depth (b) wearing process fixed abrasive silicon carbide particles: 1.– 30Х10Г10Т *2.* - 100Х9Г8Т4С



a. b.

Fig. 4 – Wear: a. – Steel with metastable austenite opposite body SiC; б. – 30В9Х3Ф, opposite body – Р18. *1.* – steel сталь 45; *2.* – 90Г9Х3Т4С; *3.* – 150Х10Г10Т4С; *4.* – 100Х9Г8Т4С; *5.* – 30В9Х3Ф (393 °С); *5.* – 30В9Х3Ф (923 °С)

Maximal strengthening depth for all tested surfacing about the same and equal to 150-200 microns. Such a character of changing hardness and strengthening depth typical of all of the tested materials. It is most distinct for surfacing, with austenite structure.

For type 90Х2Г8Т4С3 surfacing metal with a bit of residual austenite microhardness of near-surface layer is 4400 MPa. The initial microhardness before wearing – 3950 MPa. For surfacing type 30Х10Г10 with metastable austenite structure surface layer microhardness at a depth of 3.2 microns is 11000 MPa (before wearing – 3800 MPa). The change of micro hardness is 7200 MPa. For metal type 100Х8Г7Т4С3 (70…75 % – austenite, 20…22 % – martensite and 5…8 % titanium carbide grains) the average of the surface layer microhardness 11000…12000 MPa (before wearing – 4600 MPa).

4. Summary and conclusions

1. Surfacing chromium-manganese alloy steels with the structure of metastable austenite has high wear resistance to abrasive wear compared to the surfacing of tungsten steel.
2. High durability is achieved mostly by hardening the surface.
3. Durability is largely correlated with the microhardness of the surface layer.
4. With decreasing contents of metastable austenite the hardening effect and durability reduced. For surfacing with martensitic structure a slight strain hardening is measured. This points to the leading role of strain hardening of austenite and phase transformations in wear resistant surfacing alloys.
4. During tests on abrasive wear for chromium-manganese alloy steels wear intensity decreases, but for materials with different structure it is not typical.

References

1. Малинов Л. С. Марганецсодержащие наплавочные материалы / Л. С. Малинов, В. Л. Малинов // Автоматическая сварка. – 2001. – № 8. – С. 34-36.
2. Рябцев И. А. Износостойкость наплавленного металла системы легирования Fe-C-Cr-Ti-Mo / И. А. Рябцев, И. А. Кондратьев, В. Г. Васильев // Автоматическая сварка. – 2002. – № 4. – С. 48-51.
3. Филлипов М. А. Стали с метастабильным аустенитом / М. А. Филлипов, В. С. Литвинов, Ю. Р. Немировский. – М. : Металлургия, 1988. – 256 с.
4. Богачев И. Н. Кавитационное разрушение и кавитационно-стойкие сплавы / И. Н. Богачев. – М. : Металлургия, 1972. – 189 с.
5. Кальянов В. Н. Износостойкость наплавленного металла с повышенной долей карбида титана / В. Н. Кальянов, А. Н. Петренко // Автоматическая сварка. – 2004. – № 12. – С. 59-60.

References

1. Malinov, L & Malinov, V 2001, 'Marganetssoderzhashchiye naplavochnyye materialy', *Avtomaticheskaya svarka*, no. 8, pp. 34-36.
2. Ryabtsev, I, Kondratev, I & Vasileyv, V 2002, 'Iznosostoykost naplavlennogo metalla sistemy legirovaniya Fe-C-Cr-Ti-Mo', *Avtomaticheskaya svarka*, no. 4, pp. 48-51.
3. Fillipov, M, Litvinov, V & Nemirovskiy, Yu 1988, 'Stali s metastabilnym austenitom', Metallurgiya, Moskva.
4. Bogachev, I 1972, *Kavitatsionnoye razrusheniye i kavitatsionno-stoykiye splavy*, Metallurgiya, Moskva.
5. Kalyanov, V & Petrenko, A 2004, 'Iznosostoykost naplavlennogo metalla s povyshennoy doley karbida titana', *Avtomaticheskaya svarka*, no. 12, pp. 59-60.

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