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INVESTIGATION OF DEPENDENCE OF HARDNESS OF GRAIN–FERTILIZER–GRASS SEEDER CHISEL ON CHEMICAL COMPOSITION OF THE CLAD LAYER

This research work considers the comparison of composite complex alloys as an electrode for hardening of the working body of the seeder – chisel. The task of hardening is to increase the hardness of the material, contributing to the reduction of abrasive wear during the impact of the working body with the soil. According to the results of microstructural analysis of experimental samples were revealed that the initial microstructure with coarse-grained pearlite, surrounded by ferrite after hardening the size of martensitic needles decreases. Measurement of hardness on the Vickers scale allowed to obtain a graphical dependence of hardness on the chemical composition of the alloy, and it was found that the hardness of cladding with electrode T590 with four component alloy Cr25Si2MnB has the highest value of 548÷815HV. Due to the presence of nickel (CS-1) in the composition in compositionally complex alloys, the cost of the hardened part is more expensive, so it was recommended to replace with a four component boron-based alloy (T590).

Keywords: Microstructural analysis, hardened steel, complex alloys, chisel opener, grain–fertilizer–grass seeder.

Introduction

Compositionally complex alloys consisting of three or more basic elements, often referred to as high entropy alloys have received considerable attention in mechanical engineering in the last few years. Examples of such alloys are Cr25Si2MnB and Cr28Ni4Si4, and there are other five alloy components like CoCrFeMnNi, which show a significant increase in yield, strength and ductility with decreasing temperature [1].

Many authors [2; 3; 4; 5; 6] have studied the effect of chromium on the mechanical properties of parts. However, the effect of composite complex alloys on the mechanical properties, such as abrasion resistance, of parts especially working bodies of agricultural machines has not been studied.

Four-component alloy Cr25Si2MnB has boron in its composition, which is a unique micro alloying element. This chemical element is able to affect the properties of steel in ultra-low concentrations (hundredths and thousandths of a percent). The use of boron as a micro alloying additive is due to its positive effect on many of the resulting steels [7]. And in composite complex alloy Cr28Ni4Si4 contains alloying element nickel, which increases corrosion resistance, strength and ductility, but it is an expensive metal, so it is replaced by a cheaper one. Recommended hardnesses from manufacturers of Cr25Si2MnB -57÷63 HRC, and for Cr28Ni4Si4 - 53÷57 HRC.

This paper deals with the comparison of composite complex alloys as an electrode for hardening of the working body of a seeder - the chisel. The purpose of hardening is to increase the hardness of the material in order to reduce abrasive wear when the implement is exposed to the soil.

The purpose of this study is to reveal the dependence of hardness of chisels of grain–fertilizer–grass seeders made of 65Mn steel and different hardening methods on the chemical composition.

The aim of the research is to increase the wear resistance of anchor chisel openers of grain-fertilizer-grass seeders by substantiating the rational method of their surface hardening.

Hardened samples, microstructural studies and hardness measurement were carried out on the basis of laboratories of the department of «Technological machines and equipment» at S.Seifullin KATRU.

Materials and methods

Samples of chisels of openers of grain-fertilizer-grass seeders [8; 9], made of structural spring steel 65Mn, which has increased strength, toughness and resistance to wear, high resistance to small plastic deformations and relaxation resistance, has a sufficiently high hardenability, relatively low cost [10], were used for research.

Sample 1 – clad with T590 carbide electrode, sample 3 – HFC-hardened,
sample 6 – clad with CS-1 sormite, sample 7 – typical (factory) heat treatment method
Figure 1 – Tested samples for microstructures and microhardness determination,
hardened by different methods

To determine the microstructural analysis and the influence of chemical composition on microhardness, chisel samples hardened by the following method were selected: typical (factory) heat treatment method (Figure 1, sample 7), HFC-hardened at temperature within 800–820 °C in hardening medium – in oil (Figure 1, sample 3), clad with T590 carbide electrodes (Mn 1,0–1,5 %, Si 2,0–2,5 %, C 2,9–3,5 %, P ≤ 0,04, S ≤ 0,035, Cr22,0–27,0, B 0,5–1,5) of E-320Cr25Si2MnB type (figure 1, sample 1) and CS-1 (Sormite No.1) of E-300Cr28N4Si4 type (Cr=27.5 %, Ni=2.98–4.0 % and Si2.0–4.0 %) with a diameter of 5.0 mm (Figure 1, sample 6).

Microstructural analysis

Microstructural analysis of experimental samples of the coulter working organ was carried out.

Figure 2 – Machine for preliminary grinding of metallographic specimens

Polishing of the specimen surface was performed with SOI paste manually and afterwards on the M-2 Pre-grinder machine (Figure 2) using a cloth in the machine for preparation of metallographic slides. To reveal the microstructure, the microslides were etched with tsar vodka in the proportion of 3 parts of hydrochloric acid and 1 part of nitric acid, aged for 20-30 hours before use.

A Biomed MMR-1 microscope (Figure 3), which has a magnification range of 40 to 1250×, was used for microstructural analysis.

Figure 3 – Biomed MMP-1 microscope

Vickers hardness measurement

Hardness tester MET-U1A (Figure 4a) is designed for local measurement of hardness of various products by ultrasonic contact impedance (UCI) by Brinell (HB), Rockwell (HRC), Vickers (HV), Shore "D" (HSD) scales.

At the moment of measurement with an ultrasonic sensor, a constant vertical force is provided on the sensor body (at least 1.5 kg for 3-4 seconds) until a sound signal is sounded (Figure 4b).

a) Portable ultrasonic hardness tester MET-U1A b) Vickers hardness measurement process

Figure 4 – Vickers hardness measurement

Results and discussion

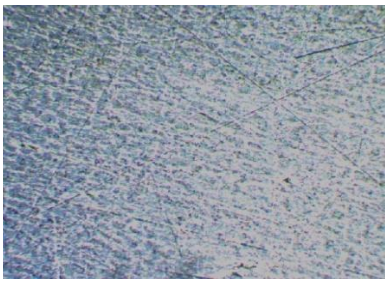
Microstructural analysis. Metallographic analysis showed that in the initial state the surface of steel 65Mn consists of ferrite and lamellar pearlite, cementite (Figure 5). Figure 5,b gives the microstructure of the diffusion layer of samples of steel 65Mnafter heat treatment, where it can be seen that in the structure of the cross section of steel 65Mn after surface hardening on the surface is observed dark-etched hardened layer of martensitic structure and a layer of thermal influence. After heat treatment the formation of martensite grains is observed, along the boundary of which there are small particles of carbides of alloying elements.

×100 ×100

a) before etching b) after etching

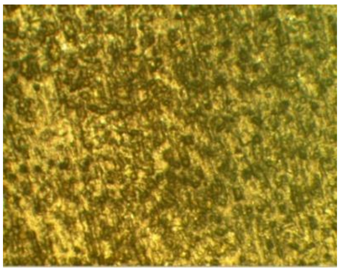
Figure 5 – Microstructure of diffusion layer on 65Mn steel by factory technology (sample 7)

The initial microstructure of the specimens before hardening was a coarse-grained pearlite surrounded by ferrite (Figure 6), with uniform grain diameter. After hardening with T590 wire and Sormite, the structure is significantly refined.



×100

a) before etching



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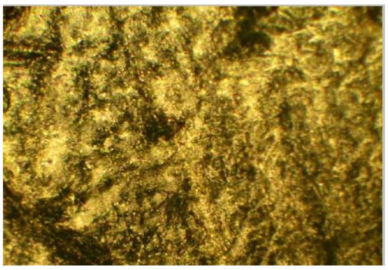
b) after etching

Figure 6 – Microstructure of diffusion layer of 65Mn steel after heat treatment (sample 3)



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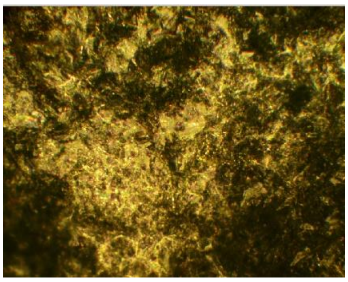
a) after hardening with T590 wire



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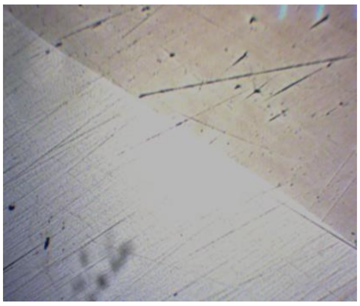
b) after hardening with Sormite

Figure7 – Microstructure of diffusion layer of 65Mn steel samples after hardening



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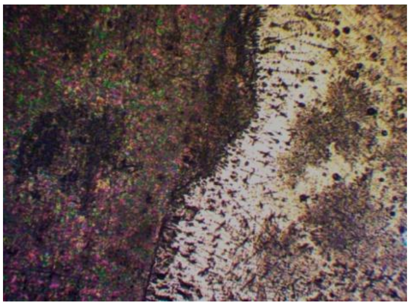
a) before etching



×100

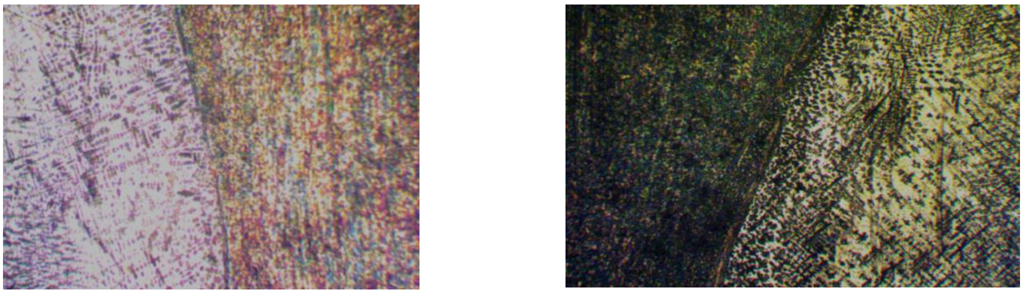
b) afteretching

Figure 8 – Cladding boundary microstructure Sample 1 before and after etching

The size of martensite needles decreases, the sormaites have larger martensite needles (Figure 7, b), and the surface hardened with T590 wire has finer needle martensite, which is formed in the diffusion layer due to secondary cementite and pearlite cementite in the structure (Figure 7, a).

Figures 8 and 9 show photos of the microstructure of the cladding boundary before and after etching of sample number 1, the light part is 65Mn steel and the dark part is hardened

T590. Small particles of chromium, manganese, silicon and boron carbides can be seen on the boundary. In the figure 9 light part belongs to steel 65Mn, dark part – hardened T590.



×100 ×100

a)after etching 30 seconds b) after etching 1 minute

Figure 9 – Microstructure of Sample 1 after 30 sec and 1 minute in tsar vodka

For most steels with a large amount of carbon, especially spring-spring steels, it is recommended to carry out the etching process in several stages in order to obtain bright structures, so during the experiment the samples were etched first for 30 seconds, then for 1 minute. The results show that the martensitic structure with pearlitic base is clearly revealed after 1 minute etching in tsar vodka.

Hardness measurement

Local hardness measurement of these specimens (Figure 1) by MET-U1A hardness tester (Figure 4a) by dynamic ultrasonic contact impedance (UCI) method on Vickers scale (HV) was performed with 20 repetitions and the experimental results are summarized in Table 1.

The results show that the microhardness of bit number 1 on Vickers scale varies between 815÷548HV, sample 3 – 391÷112HV, sample 6 – 657÷305 HV and sample 7 – 333÷100HV. Consequently, sample 1, clad with T590 carbide electrode has almost 2.5 times more hardness than sample 7. At the same time, HFC-hardened sample number 3 has almost similar hardness measurement results with sample 7, heat treated according to the standard method. And the sample numbered 6 clad with CS-1 Sormite has 1.2 times less hardness than sample 1, but almost 2 times more hardness compared to sample 7.

The chemical compositions by the GOST of the selected samples indicate that the high values of chisel hardness from the Vickers measurement results (Table 1) depend on the complex composition of the clad layer. The electrode based on Manganese-Silicon-Boron-Chromium has the highest readings than in the electrode based on Manganese-Silicon-Nickel-Chromium with low chromium content, i.e. T590 has 22,0÷27,0% chromium, while CS-1 has 25,0÷31,0 % chromium.

Table 1 – Hardness measurements of experimental specimens on the Vickers scale, (HV)

Experience number	Sample 1	Sample 3	Sample 6	Sample 7
1	815	243	382	308
2	790	356	305	164
3	736	229	557	228

4	624	183	466	331
5	548	359	385	237
6	775	223	555	149
7	679	320	657	287
8	733	245	520	206
9	724	289	560	169
10	598	391	474	180
11	575	138	380	126
12	763	118	613	105
13	628	153	584	147
14	661	178	359	133
15	709	154	523	117
16	644	320	577	167
17	740	112	518	331
18	739	185	649	333
19	709	135	494	327
20	713	149	534	100

The content of alloying elements in steel 65Mn is 1.76÷2.46%, in T590 electrode – 28.47÷36.07% and in CS -1 electrode - 34.3÷44.6%. Taking into account the data of measurement experiments and the total percentage of alloying elements in the composition of electrodes, it is possible to construct a graph of dependence (Figure 10) in Mathlab of only two samples 1 and 6, since during HFC hardening of the material (sample 3), the composition of alloying elements remains the same as in the original sample 7.

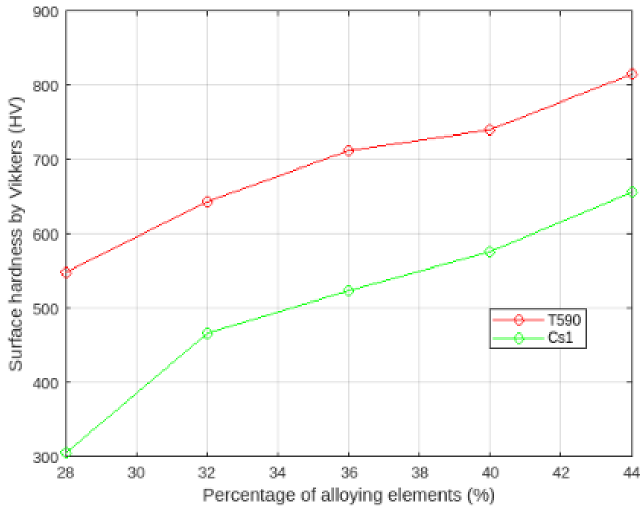


Figure 10 – Graph of surface hardness dependence on alloying elements composition

According to the graph of dependence (Figure 10) it is possible to confirm that despite the high content of alloying elements in the alloy is of great importance, for example, having in its composition boron hardness in the electrode T590 is greater than that of sormite, which contains expensive metal nickel in its composition.

As a result, from Table 1 and Figures 1-10 it can be noted that the sample No.1, hardened full working surface by surfacing of T590 electrode, is resistant to abrasive impact due to hardness 815HV and uniform martensitic-perlitic microstructure.

Conclusions

1. According to the results of microstructural analysis of hardened samples, it was found that the samples hardened by surfacing with T590 and Sormite electrodes, as well as heat-treated samples have secondary cementite and pearlite cementite in the final structure, which increase the hardness of the material.

2. The composition of alloying elements in composite complex alloys, especially boron and nickel, significantly affects hardness. However, the presence of nickel (CS-1) increases the cost of the hardened part, so it is recommended to replace it with a four component boron-based alloy (T590).

3. T590 clad with carbide electrode has almost 2.5 times more hardness 815÷548HV than sample 7, heat treated according to the typical method. The HF-hardened sample has almost similar results of hardness measurement with sample 7, 391÷112HV and 333÷100HV respectively. And the sample clad with CS-1 sormite has 1,2 times less hardness (657÷305 HV) than T590, but almost 2 times more hardness of comparisons with sample 7.

4. As the most optimal method of bit hardening in coarse abrasive environment for production conditions and agricultural enterprises it is possible to recommend surfacing of working bodies of seed drill coulters with T590 electrodes instead of typical factory heat treatment.

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АСТЫҚ-ТЫҢАЙТҚЫШ-ШӨП СЕПКІШ ҚАШАУЫНЫҢ ҚАТТЫЛЫҒЫНЫҢ БАЛҚЫТЫЛҒАН ҚАБАТТЫҢ ХИМИЯЛЫҚ ҚҰРАМЫНА ТӘУЕЛДІЛІГІН ЗЕРТТЕУ

Бұл зерттеу жұмысы сепкіштің жұмыс органының, сіңіруші қашауының, қаттылығын арттыруда электрод түріндегі композициялық күрделі қорытпаларды салыстыруды қарастырады. Қатайту міндеті - топырақпен жұмыс органының әсерінен абразивті тозуды азайтуға көмектесетін материалдың қаттылығын арттыру. Эксперименттік үлгілерді микроқұрылымдық талдау нәтижелері бойынша ферритпен қоршалған ірі түйіршікті перлиті бар бастапқы микроқұрылым қатайтылғаннан кейін мартенсит инелерінің мөлшері азаятыны анықталды. Викерс шкаласы бойынша қаттылықты өлшеу қаттылықтың қорытпаның химиялық құрамына графикалық тәуелділігін алуға мүмкіндік берді, төрт компонентті Х25С2ГР қорытпасы бар Т590 электродының беткі қаттылығының ең үлкен мәні 548÷815HV екенін анықталды. Композициялық күрделі қорытпаларда никельдің (ЦС-1) болуына байланысты қатайтылған бөлшектің құны қымбатырақ, сондықтан бор негізіндегі төрт компонентті қорытпаға (Т590) ауыстыру ұсынылды.
Кілтті сөздер. Микроқұрылымдық талдау, қатайтылған болат, күрделі қорытпалар, сіңіруші қашауы, астық-тыңайтқыш-шөп сепкіші.

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ИССЛЕДОВАНИЕ ЗАВИСИМОСТИ ТВЕРДОСТИ ДОЛОТА ЗЕРНОТУКОТРАВЯНОЙ СЕЯЛКИ ОТ ХИМИЧЕСКОГО СОСТАВА НАПЛАВЛЕННОГО СЛОЯ

В данной исследовательской работе рассматривается сравнение композиционно сложных сплавов в качестве электрода для упрочнения рабочего органа сеялки - долота сошника. Задачей упрочнения является увеличение твердости материала, способствующего снижению абразивного *износа при воздействии рабочего органа с почвой. По результатам микроструктурного анализа экспериментальных образцов были выявлены, что исходная микроструктура с крупнозернистым перлитом, окруженный ферритом после упрочнения размер мартенситных игл уменьшается. Измерение твердости по шкале Виккерса позволило получить графическую зависимость твердости от химического состава сплава, при этом установлено, что твердость наплавки электродом Т590 с четырех компонентным сплавом Х25С2ГР имеет наибольшее значение 548÷815HV. Из-за присутствия в составе никеля (ЦС-1) в композиционно сложных сплавах стоимость упрочненной детали получается дороже, поэтому была рекомендована замена на четырехкомпонентный сплав на основе бора (Т590).*

Ключевые слова. Микроструктурный анализ, упрочненная сталь, сложные сплавы, долото сошника, зернотукотравяная сеялка.

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