EFFECT OF MECHANICAL AND CHEMICAL COMPONENTS OF THE SOILON RESISTANCE OF FUNCTIONAL PARTS OF AGRICULTURAL MACHINES

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Due to wear processes of metallic materials of agricultural machines parts in intensive abrasive wear, especially owing to chemical potential of environment cause a permanent deformation by means of shifts inside the material and mutual displacement of the whole crystals. Experiments conducted study the effect of mechanical and chemical factors of soil wearing environment on mechanical properties of worn surfaces of agricultural machines parts and quantify a rate of increase of micro-hardness, depth and size of hardening of surface layer. The results of an experiment performed with CK55, X8Cr17 and X6CrNiMoTi steel confirmed that hardening is manifested in deferent way on each investigated material what depends on physico-chemical properties of the given material. Results of chemical analysis of materials used as well as results of measurement of macro and micro-hardness are in tables. Intensity of wear, micro hardness of worn surface of a sample and depth of hardening depend not only on acting load, but on the character and chemical composition of soil wearing environment as well. Materials of ferrite+pearlite and austenite structures harden in connection with their plasticity.

abrasive wear; soil; mechanical factors; chemical factors; passivity

INTRODUCTION

Upon operation of the farm machines and equipments, through their functional parts, wear processes take place. Characteristics of these operations and their intensity depend on a number of operational and metallurgical factors which lead the machines and machinery equipments to reach the top condition, where these machines cannot perform the functions and jobs for which they were manufactured.

The metal as a material cannot be compensated in many fields of manufacturing due to its distinguished characteristics. Whereas industry and treatment of metallic materials is considered a very expensive operation as regards energy and raw materials, research for methods of improvement of their manufacturing, particularly using thereof is still continuing.

One of these methods is deepening the study of the metallic materials characteristics and disposition under complicated tension conditions and acquaintance of all metallurgical and operational factors, which cause wear of the metallic materials.

Due to intervention of several specialties in this field such as mechanics, solidity, elasticity, tribology, production technology and treatment of metals etc. Study of the characteristics and disposition of the metal materials since their manufacturing up to arrival of the top condition is considered very wide field. Research of reasons of the metallic materials wear is considered a very complicated matter, because it depends on a large number of different factors and effects.

Should this study not determine the main and effective parts, the next study will be very complicated. Therefore, it is inevitable to fully evaluate the studied case and to use the concluded information in research, industrialization and application fields aiming at approaching new results to help the increase durability of the machines and equipments and their operational capacity, improve their quality and technical level and develop new materials, as well as to limit costs of manufacturing and passive effects against bio-environment.

Most important reasons of farm machinery parts defect which limit the machine life and its operational capacity are phenomena of tribology, which studies all phenomena of friction and wear, where the friction which results wear of all machine functional parts is resistance of the mutual movement, which contacts the surfaces of at least two materials in direction of its movement. Blaskovic et al. (1990) defines wear as decreasing of the mass and dimensions of the solid bodies surfaces as a result of the mutual effect of these surfaces as well as causing loss of a part of the movement energy of these bodies cause damages of the machines through wear surpass other damages such as wear fractions and damages result in excessive tension etc.

Nofal (1997) classified important kinds of wear as adhesive wear, abrasive wear, erosive wear, cavity wear, fatigue wear and vibrating wear.

Abrasive wear (which is subject of this research), which is characterized by separation of the material granules from the operating surface of the machine part due to the effect of a rough surface and another solid body or due to the effect of free and solid granules, was studied by Quirke et al. (1988). They consider abrasive wear as a kind of wear which causes damage and defect of the functional parts of the farm machines and equipments which have direct contact with soil, whereas the latter contains solid and rough granules abrading thereof.

This kind of abrasive wear in the soil is normally evaluated in quantitative methods used for testing manufacturing of the metallic materials under laboratory conditions on the basis of decrease of the mass. Allen et al. (1986) shows that this kind of wear does not depend on type, characteristics and hardness of metals from which the parts of farm machines and equipments operating in the soil are made only, but on chemical and microstructure of both metal and soil, because wear in the soil occurs according to a mechanico-chemical principle, whereas the soil does not include solid and rough granules only, but also many chemical parts help degradate metallic materials such as acids, remnants of plants and organic and inorganic fertilizers etc. Such a wear is not distinguished only with shortage of mass or dimensions of the metal piece (sample), but with full change of the metal quality, characteristics of surface layers, tension case and chemical structure of these layers etc. The surface layer of the metal represents a study material on which all degradation stage are focused. We should also deepen study of this kind of wear through the research of eroded layers of the metal and classification and explanation of wear stages aiming at disclosing its internal laws.

Accordingly, and on the basis of the above mentioned, the goal of my present study is: Studying an effect of mechanical and chemical components of the soil on mechanical properties of agricultural machines parts.

MATERIALS AND METHODS

To realize goals of my present research, I have studied and searched operations of wear of metallic materials in the soil conditions in quality and quantity as follows:

1 – Selection and classification of the metallic materials utilized and carrying out the following laboratory experiments:
- Chemical analysis of the utilized metallic materials,
- Definition of the microstructure of the utilized materials,
- Measurement of hardness HV.

2 – Selection of the soil kind utilized,

3 – Production of samples,

4 – Carrying out wear against the samples aiming at:
- Comparison of resistance of metallic materials against wear in soil,
- Measurement of micro hardness of the eroded surfaces.

Utilized materials

To research operations of wear of the metallic materials in the soil conditions, I have selected the following metallic materials, which vary according to their physico-mechanical characteristics.

1. CK55
2. X8Cr17
3. X6CrNiMoTi

Table 1. Chemical analysis of used materials

Element (%)	CK55	X8Cr17	X6CrNiMoTi
C	0.55	0.22	0.04
Mn	0.69	0.46	1.97
Si	0.22	0.34	0.52
P	0.01	0.026	0.028
S	0.04	0.034	0.017
Cr	0.21	16.70	17.88
Ni	0.16	1.45	12.6
Mo	0.17	0.11	2.46
V	0.011	0.03	–
Ti	–	–	0.03

Table 2. Hardness of used materials

Material	HV-30
Ck55	240
X8Cr17	265
X6CrNiMoTi	195

The said materials were chemically analyzed by digital scanning microscope-zeiss. Table 1 shows results of this analysis.

The microstructures of the said materials were studied by Neophot Microscope. Figs 1, 2 and 3 show their internal structure.

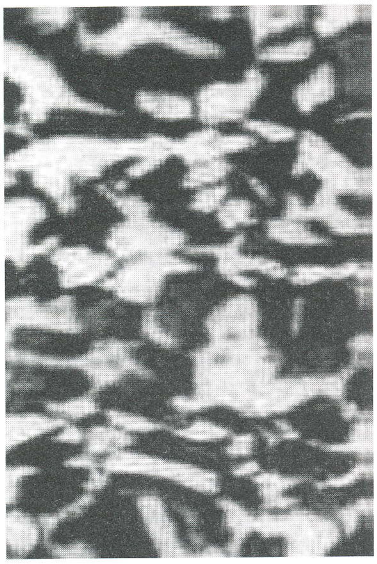
Results of the study of chemical analysis and microstructure of these materials prove that:

1. Steel CK55 is formed of ferrite and pearlite granules. This steel is utilized for manufacturing the operational parts of the equipments and machines which have direct contact with soil which need immunity against abrasive wear.
2. Steel X8Cr17 is formed of ferrite and sorbite and distinguished with high immunity against rust and utilized for manufacturing machine parts whose functions concentrate in liquids and water.
3. Steel X6CrNiMoTi is formed of austenite granules. It is characterized with its high immunity against intercrystalized rust and it is utilized for manufacturing of the machine parts operating in concentrated organic and inorganic acids.

Mechanical hardness of these metals was determined as well. Table 2 shows these values.

Utilized soil

Samples were eroded in the kaolintic clay soil as a soil representing main kinds of the soil. However, due to the difference of the soil physico-mechanic characteristics and for the sake of this research, results to be nearer to practical conditions, I have mixed the clay soil with sandy soil in rate of 4 : 1 aiming at increase of intensity of mechanical effect of the soil against the metal.



600x

Fig. 1. Microstructure of CK55

600x

Fig. 2. Microstructure of X8Cr17

600x

Fig. 3. Microstructure of X6CrNiMoTi

Utilizing fertilizers in soil much affect intensity of functional parts wear of the machines used in soil, therefore, I have added chemical fertilizer ammonium sulphate $(NH_4)_2SO_4$ to the soil and thoroughly mixed it. It increases intensity of chemical effect of the soil against the metal. Ammonium sulphate solutions react slightly acidic. In presence of metallic material that give an alkaline reaction, ammonia will form. Many metals are affected by ammonium sulphate in combination with moisture.

Production of samples

Necessary samples for the research were produced from the metallic materials used in measurements 10 x 25 x 80 mm. Six samples of every material were produced (total: 18 samples).

Conducting wear against samples

Wear was conducted against samples of used materials through utilizing laboratory apparatus (Fig. 4) which is consisted of a circle canal as shape of U letter to be operated through electric engine and gear, which transmit movement from the engine to the canal.

The canal will be filled in with necessary quantity of soil, to be mixed by simple tooth harrows. The sample will be well fixed inside the sample holder and the necessary pressure against the sample will be determined through a pressed spring. One pressure 0.15 MPa was effected against every sample. Upon wear, the soil moisture was 15%, canal speed was 3 $km.h^{-1}$ and experiment period for every sample was 20 minutes, i.e. every sample passed a distance of 1000 m upon wear.

I have symbolized the used depending on chemical structure as follows:

Soil A: moisture W = 15% (H_2O); soil B: moisture W = 15% $(NH_4)_2SO_4$

RESULTS

Table 3 shows values of wear for every material by numbers. Table 4 shows changes taken place in value of micro-hardness and depth influence for used materials.

DISCUSSION

The value of wear of every metallic material was defined through finding the difference of the sample mass before and after wear in the soil.

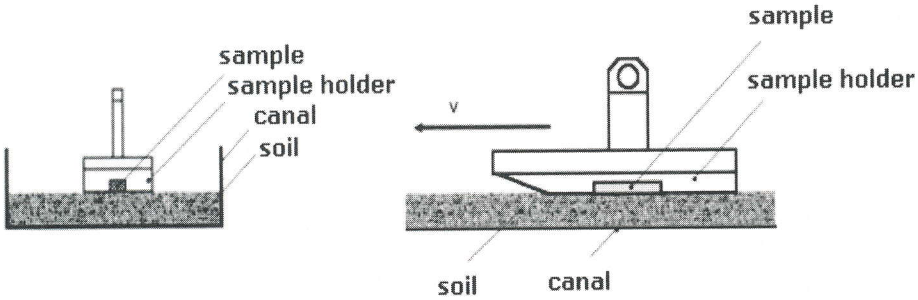


Fig. 4. Laboratory apparatus

Table 3. Values of wear of used materials in defined conditions

Soil	CK55		X8Cr17		X6CrNiMoTi	
	ΔG (g)	ϕ ΔG (g)	ΔG (g)	ϕ ΔG (g)	ΔG (g)	ϕ ΔG (g)
A	0.4860 0.4763 0.4852	0.4825	0.4456 0.4650 0.4802	0.4636	0.6583 0.6709 0.6952	0.6748
B	0.2865 0.3179 0.2986	0.3010	0.3084 0.2996 0.2977	0.3019	0.6158 0.6487 0.6108	0.6251

Results of measurement of this decrease in the mass point out that the value of wear of every material varies according to difference of its physico-mechanical characteristics and microstructure. They also depend on chemical structure of the soil and pressure affecting the samples used through the experiments.

Utilization of ammonium sulphate $(NH_4)_2SO_4$ led to devaluation of wear value for the used materials. Whereas the wear value in the soil B was less than is value in soil A, through using this chemical structure, wear value decreased for CK55 in rate of 37.6%, for X8Cr17 34.8% and for X6CrNiMoTi 7.4%.

Among the above mentioned results, we find out that existence of ammonium sulphate $(NH_4)_2SO_4$ in the soil leads to devaluation of the wear value. This fact interprets formation of secondary layers of the steel (protective membrane), characterized by high mechanic characteristics resisting wear.

Results of measurement of micro-hardness of the surface layers of the metallic materials used after wear indicate that higher value of hardness is reached to over the surface, while hardness decreased to its fixed value (basic hardness of the material) at surface layers.

Hardness of the metallic materials used varies in accordance with kind of material and microstructure.

Micro-hardness of the used material surfaces and depth of the influence are increasing through using ammonium sulphate $(NH_4)_2SO_4$. Reaction operations among ammonium sulphate $(NH_4)_2SO_4$ added to the soil with the metallic surfaces caused formation of secondary layers with a high hardness.

The highest increase of micro hardness value was obtained with austenitic steel X6CrNiMoTi, due to its high strength and its ability of plastic deformation, followed by CK55-ferrite+pearlite steel and X8CR17 ferrite+sorbite steel. Results indicate that the highest depth of effect was for steel X6CrNiMoTi, followed by CK55 and X8CR17.

The above mentioned tables and shapes indicate to large effects of ammonium sulphate $(NH_4)_2SO_4$ against mechanical characteristics of the metallic surfaces. On this ground, it is considered as passivator.

Results of this study indicate that immunity of the materials against wear in soil conditions depends on several factors among which hardness of materials, whereas whenever the material hardness increases, its immunity will increase. This hardness depends, of course, on microstructure of the material and every part of this structure defines range of its immunity. Ferrite+pearlite steel is characterized with a low immunity compared with ferrite+sorbite steel, because the ferrite as a part of microstructure is distinguished with strength and ferrite wear and isolation from the surface is simply carried out, particularly when the strength (pressure) affecting thereof is high.

As for ferrite+sorbite steel, it contains a high rate of chrome where it increases its hardness and immunity against rust, however, its hardness is near from hardness of ferrite+pearlite steel and accordingly, its immunity. Therefore it is not economically preferable to be used in the soil. This means that the mixing the metals with other parts, such as chrome, does not guarantee in much cases increase of the metal immunity. Austenite steel has immunity lower than other metals used, but its ability for hardening and attaining hard surface layers was very high compared with the other metals, due to its high strength and low hardness and ability of plastic deformation.

CONCLUSION

The paper presents results of experimental investigations of mechano-chemical form of abrasive wear of agricultural machines parts.The ideal structure of steel should secure the highest immunity against wear in the soil, should be formed of semi-stable austenite, of such and inhomogeneous structure represents a strong relatively part able to absorb the biggest possible quantity of energy and accordingly joining solid granules tightly. Phenomenon of non-activity or passivity taken place upon wear of the metallic materials in the soil, may be used in other fields, such as addition of passivator to lubricating oils etc.

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Table 4. Values of micro hardness and depth influence of worn materials after wear in defined conditions

Depth	Material					
	CK55		X8CR17		X6CrNiMoTi	
h (μm)	HVM		HVM		HVM	
	soil A	soil B	soil A	soil B	soil A	soil B
0	**298**	**323**	**288**	**296**	**335**	**360**
1	295	320	286	296	332	356
2	285	315	280	292	328	350
3	282	312	271	285	322	346
4	275	304	262	278	318	335
5	268	298	258	265	311	328
6	260	295	245	259	310	315
7	258	295	240	255	308	312
8	256	293	242	251	304	309
9	251	290	235	251	292	307
10	248	288	**233**	250	289	305
11	246	286	232	246	282	296
12	246	285	233	242	275	290
13	245	280	233	240	270	287
14	245	271	234	240	265	282
15	242	268	234	237	262	280
16	238	262	233	235	260	277
17	232	259	233	234	258	276
18	225	257	233	**233**	257	273
19	222	252		233	256	273
20	218	248		233	254	271
21	217	240		234	255	266
22	**214**	237		233	251	265
23	214	233		233	248	260
24	215	225		233	245	258
25	214	219			243	253
26	214	218			241	245
27	214	216			238	242
28	213	**214**			238	240
29	213	213			235	240
30	214	214			231	236
31		214			230	234
32		214			228	234
33		214			226	233
34		215			222	232
35		213			218	229
36		214			215	229
37					212	227
38					213	227
39					210	220
40					207	219
41					202	212
42					199	207
43					193	202
44					192	201
45					186	202
46					187	192
47					183	191
48					**182**	190
49					182	187
50					182	185
51					183	184
52					182	**182**
53					183	182
54					182	182
55					182	183
56					183	182
57						183
58						181

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Vliv mechanických a chemických složek půdy na rezistenci funkčních součástek zemědělských strojů.

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Procesy opotřebení kovových materiálů součástek zemědělských strojů při intenzivním abrasivním opotřebení, zejména následkem chemického potenciálu životního prostředí, způsobují trvalou deformaci a posuny v materiálu a vzájemné posuny celých krystalů.

Byly prováděny pokusy, které se zabývaly vlivem mechanických a chemických faktorů životního prostředí, způsobujících opotřebení půdy, na mechanické vlastnosti opotřebených povrchů součástek zemědělských strojů a kvantifikací intenzity nárůstu mikrotvrdosti, hloubky a velikosti tvrdnutí povrchové vrstvy.

Výsledky pokusu prováděného s ocelí CK55, X8Cr17 a X6CrNiMoTi potvrdily, že tvrdnutí se projevuje jinak na každém zkoumaném materiálu v závislosti na fyzikálně-chemických vlastnostech daného materiálu.

Výsledky chemické analýzy použitých materiálů a výsledky měření makro- a mikrotvrdosti jsou uvedeny v tabulkách. Intenzita opotřebení, mikrotvrdost opotřebeného povrchu vzorku a hloubka tvrdnutí závisí nejen na působícím zatížení, ale i na charakteru a chemickém složení půdy vystavené opotřebení způsobenému životním prostředím. Materiály struktur ferit+perlit a austenit tvrdnou následkem plastických deformací.

abrazivní opotřebení; půda; mechanické faktory; chemické faktory; pasivita

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